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CONCERNING SERPENTS.

By ELIAS LEWIS, Jr.

FEW animals are more universally feared and detested than serpents. Their presence startles us, however inoffensive they may be. Nor can the gracefulness of their motion, or beauty of color, conquer the discontent we feel when we see them gliding in our path, or coiled and glistening in the sunshine, in which they delight. The enjoyment of many a summer's ramble has been impaired from this cause, and we fear our article may be as distasteful to many persons as are the objects of which it treats. But we may remember that serpents, no less than more attractive creatures, are important in Nature's economies. Their structure is a marvel of mechanical adaptation, less complicated, perhaps, but as perfect in every detail as is that of mammals and birds, and the mechanism which rolls the human eye is not more complete, and scarcely more wonderful, than that which moves the fangs of a viper. Perhaps, in the study of Nature, we should estimate objects by their fitness, rather than by their attractiveness or beauty.

"The serpent," observes Prof. Owen, "is too commonly looked down upon as an animal degraded from a higher type. . . . But it can outclimb the monkey, outswim the fish, outleap the jerboa; it has neither hands nor talons, yet it can outwrestle the athlete, and crush the tiger in its embrace." Serpents, in their mode of locomotion, are creeping animals, as their name implies, and constitute an order of the great class Reptiles. This term also implies creeping, but includes orders of animals which have limbs for locomotion, and do not creep. Of these, turtles, lizards, and crocodiles, are familiar instances; so that animals of several species, which run, walk, or swim, are included in the same class with those which creep. All of these, however, are cold-blooded, the temperature of the body differing but few degrees from that of the surrounding air or water. Their coldness is always

obvious to the touch, and this is true with those found in hot as well as in temperate climates, and adds greatly to their repulsiveness.

Fig. 1.

Port Natal Rock-Snake, or Python.

Of serpents, their general form and structure are the same. Their bodies are rounded and elongated, and covered with a scaly skin. The vertebral column is continuous with the length of the body, and is divided into joints from 200 to 400 in number, but in the large pythons (Fig. 1), as stated by Dr. Carpenter, 422 vertebral joints have been counted. To about 360, or $\frac{4}{5}$ of these, were attached pairs of movable ribs. A rattlesnake, with 194 vertebræ, had 168 pairs of ribs. The vertebræ of the serpent are united by a most perfect ball-and-socket joint, and the ribs are joined to the vertebræ in a similar manner. These, held and worked by complete muscular adjustment, give to several their wonderful flexibility, strength, and crushing power.

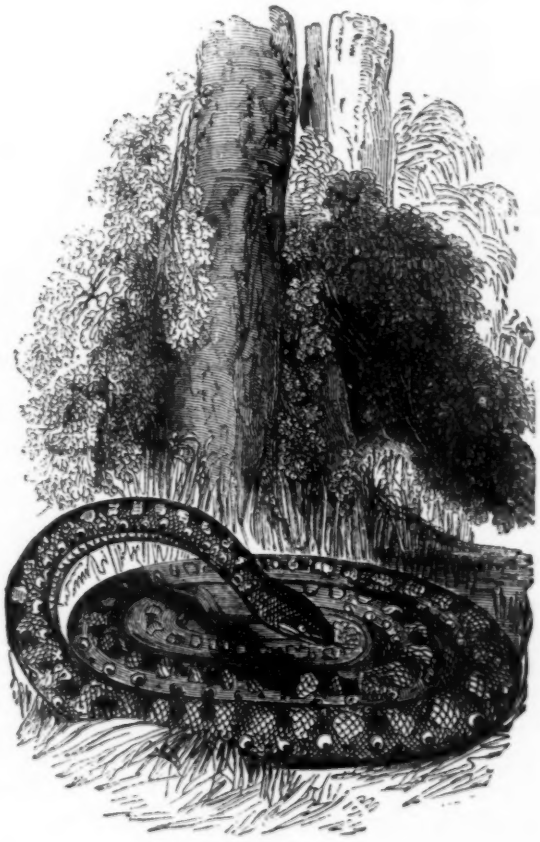
The well-known boa-constrictor, and the aboma, or ringed boa of South America (Fig. 2), are illustrations of this class of serpents, the term constrictor being given from their power to close upon and compress whatever is within their folds.

The structure of the backbone of a serpent has direct relation to its locomotion, for it is without limbs, and rudiments of pelvic bones are found only in the boas, pythons, and a few other species. But, where the type shades off into allied reptilian forms, the rudimental limbs are developed and prominent.

We read that the curse pronounced upon the serpent was, "upon thy belly thou shalt go," and the inference seems to be that, previous to that time, its mode of progression was not upon its belly. This would imply a great anatomical change in the structure of the creature at the time in question, a change which, so far as we are aware, is not proved by paleon-

tological research, and the expression is probably a figurative one, as observed by Dr. Buckland. Serpents progress by the "foldings and windings they make on the ground," and the stiff, movable scales which cross the under portion of the body; but the windings are sideways, not vertical.

FIG. 2.



ABOMA, OR RINGED BOA.

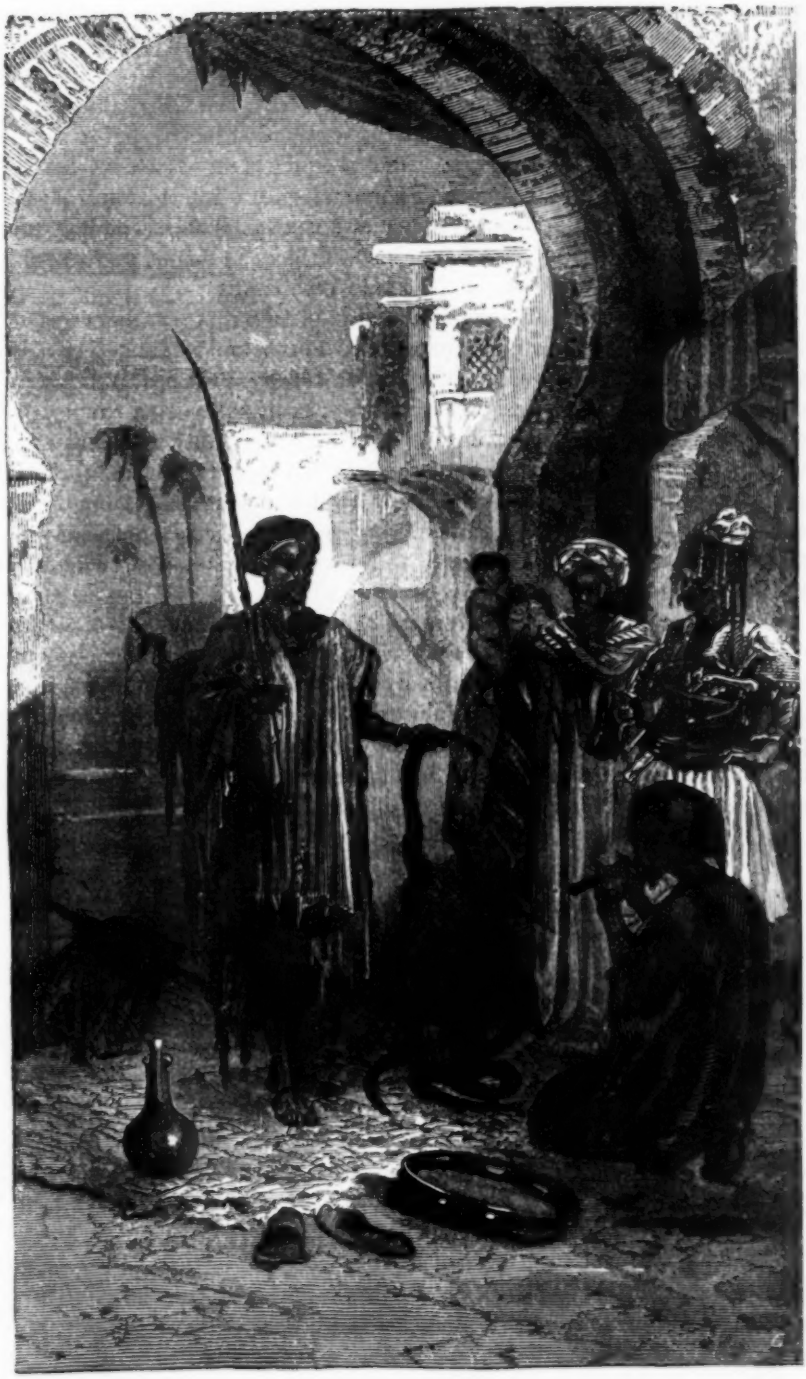
The structure of the vertebræ is such, that upward and downward undulations are greatly restricted, and many illustrations, showing sharp vertical curves of the body, are exaggerations. Most persons have seen snakes glide slowly and silently, without any contortion. They seem to progress by some invisible power; but, if permitted to move over the bare hand, an experiment easily tried, a motion of the scales will be perceived. These are elevated and depressed, and act as levers, by which the animal is carried forward. Nor can a serpent progress with facility on the ground, without the resistance afforded by the scales. It is stated that it cannot pass over a plate of glass, or other entirely smooth surface. We saw the experiment tried, by

placing a small pane of glass in a box, in which was a common black snake. He was made to pass over it repeatedly, but evidently found that he had no foothold on it; and the third time, as he approached it, elevated the fore-part of his body slightly, and brought his head down beyond the glass, and, on passing, his body seemed scarcely to touch it. This gave an opportunity to witness the wave-like movement of the scales, that is, of their elevation, which runs from the head to the tail, enabling the animal to move continuously, instead of by a series of minute pushes, as would occur if all the scales be lifted and depressed at once.

In the moulting of the snake, which occurs yearly, and sometimes oftener, the outer covering of these creeping scales is shed; this is true also of the covering of the eyes, so that the cast epidermis represents, with great distinctness, the external features of the animal. In moulting, the outer skin is broken along the back, near the head, and the animal emerges, frequently drawing with him the skin, turning it inside out. Prof. Owen states, however, that in one instance exuviation commenced by the snake rubbing the skin loose around its jaws, working it back against the sides of its cage, when, putting its head through coils made by its own body, it pressed back the skin, turning it outward. We have observed that the black snake, on moulting, becomes more sensitive and irritable, but shy, and inclined, for a day or so, to keep close in a corner of his cage. The scaly covering of serpents must diminish their acuteness of touch; but we have found them sensitive to exceedingly slight irritation. They are without an external ear, and the phrase "deaf as an adder" is a familiar one. Nevertheless, they have organs of audition beneath the skin or protecting membrane, and we know by experiment that snakes hear and distinguish sounds, and are said in some instances to recognize the voice of their keeper. Some species, it has been observed, are influenced by music, and we quote the statement by Chateaubriand of an incident witnessed by himself. He says: "The Canadian began to play upon his flute. The snake (a rattlesnake) drew its head backward, its eyes lost their sharpness, the vibrations of its tail relaxed, and, turning its head toward the musician, remained in an attitude of pleased attention."

The snake-charmers (Fig. 3), familiar to travelers in Eastern countries, handle cobras with apparent impunity, cause them to advance or retreat, to coil and uncoil, to bow their heads, or bring their deadly mouths to their own by musical sounds, either vocal or instrumental. A story is related of an English gentleman, residing in a mountainous part of India, who was compelled to desist playing upon a flute because the music attracted serpents to his residence. The sense of taste in serpents must be very feeble, as it is quite unserviceable. They swallow their food whole, nor have they any teeth by which mastication can be accomplished. Their sense of smell is also obtuse. The

FIG. 8.

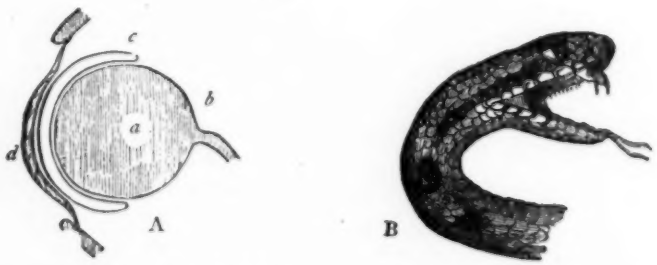


SNAKE-CHARMERS.

organs by which this is effected are near the muzzle, but, according to Cuvier, they are without the sinuses which exist in the heads of mammals. We have tested this sense in several species of snakes, but only pungent odors seem to specially annoy them. The tongue of the serpent is a harmless appendage, tough, horny, and double-pointed; and, like the same member in man, has a wonderful propensity to be in motion. That snakes sting with their tongues is an old but erroneous opinion. Perhaps our own species is not equally innocent in that respect. All serpents are carnivorous, and nearly all seize and swallow living food. Their teeth are bony, hard, conical in shape, and exceedingly sharp-pointed. None of the class have grinding or cutting teeth. They are formed for holding their food, not to grind, crush, or cut it. Moreover, all their teeth are recurved in form and position; that is, they point in or backward, so that an object once seized can scarcely escape, and, if the jaws be fully distended, could only with great difficulty be ejected. Instances are given where serpents have died from their inability to swallow what they could not eject from their throats, and it is obvious that life could not continue a very long time under such circumstances, for, as Prof. Owen observes, "while swallowing, the tracheæ may be so compressed that no air can pass, and their only resource is what is contained in the lungs."

In the non-venomous species, which includes those that constrict or crush their prey, are found four rows of teeth in the upper jaw and arch of the mouth, and two rows in the under jaw. Venomous species have usually no more than two rows above, which are on the palatal arch, and two below; but they have on the upper jaw two or more poison-fangs, as shown in Fig. 4, an account of which makes the most fearful chapters in the history of this family of reptiles.

FIG. 4.



A. DIAGRAMMATIC SECTION OF THE EYE OF A VIPER.

a. Eyeball; *b*. Optic nerve; *c*. Chamber into which tears are poured; *d*. Epidermic layer covering the eye.

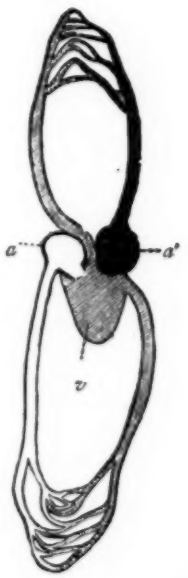
B. HEAD OF VIPER, SHOWING POISON-FANGS.

We have observed that serpents swallow their food whole. They make a meal from a mouthful, but the mouthful is sometimes a very large one, for they will swallow animals twice or thrice their own

diameter. This is permitted by the extraordinary expansibility of their body; but the enlargement of their jaws is a complicated phenomenon. In the act of swallowing, they yield at every point, sideways as well as vertically. The elastic integuments which hold the parts of their jaws in place give way, and the apparently small mouth becomes an enormous one.

Digestion proceeds slowly, and, if the meal be excessive, as it often is, the serpent remains sluggish and comparatively helpless a long time. "They have been kept four, six, and eight months, without being fed, and with very little apparent waste of substance." Bruce reports that he kept specimens of the cerastes, or horned-snake, two years in a glass vessel without food, during which time they cast their skins as usual.

FIG. 5.



CIRCULATING SYSTEM OF REPTILE.

a. Auricle receiving worn-out venous blood from the system; *a'*. Auricle receiving vitalized blood from the lung; *v*. Ventricle in which the two bloods are mixed, and from which it is thrown into the general circulation.

Vital activity in serpents is low. In mammals, the normal mean temperature is from 95° to 105° Fahr., and this must be maintained, or disease supervenes. With serpents, the temperature is a few degrees only above that of the surrounding atmosphere, and varies with it. Thus, it may range, in their healthy active state, from 60° to perhaps more than 80° Fahr. The temperature of a serpent was found, by Hunter and others, to be 88.46°, that of the air being 81.5°. The temperature of a frog was 48° in water at 44.4°. If the atmosphere be

continuously at 60°, some of our common snakes become sluggish and inactive. In both mammals and reptiles the source of internal heat is the same, the difference being in degree only. The low temperature of serpents (as of other reptiles) arises from the structure of their vital organs, by means of which their blood is imperfectly oxygenized. As the "worn-out" or venous blood enters the heart, it is *mixed* with the vitalized blood from the lung (there being, in most species, only one lung and a rudiment of another), and it is this mixed blood which is thrown into the general circulation, as shown in Fig. 5. The blood of a serpent has been said for this reason to be

FIG. 6.

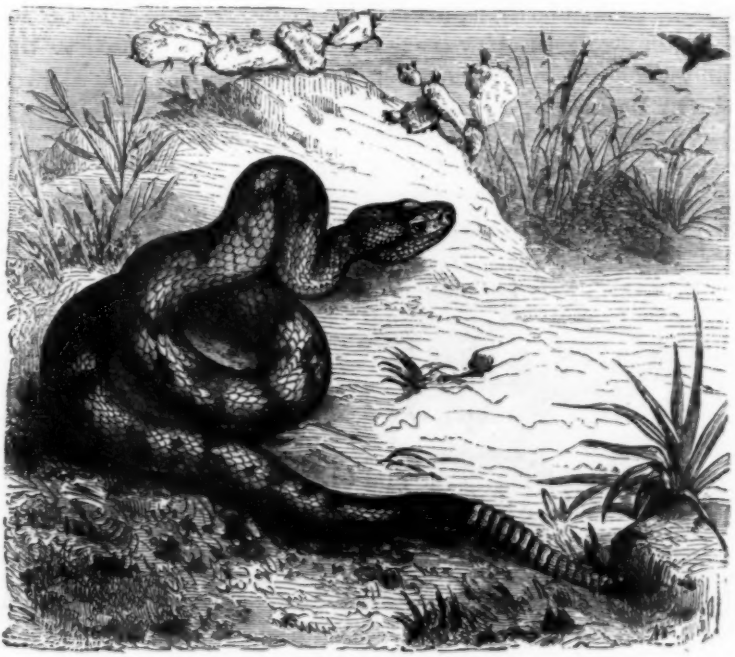
ANACONDA.

only half alive, and their functions are accordingly sluggish and dull. Their power of existence for long periods without food, and with little waste of tissue, is chiefly incident to their low vitality.

Hibernation is with them a period of profound torpor. In our temperate climates they gather in large numbers, in some hole, or bur-

row in the ground, or in clefts of rocks, for their winter sleep. We once saw twenty-six black snakes taken from one burrow beneath the roots of a partially-fallen tree, in February. Other observers have found a much larger number. We are informed that more than 300 have been found in a single burrowing-place, and that many species, venomous and non-venomous, sometimes resort to the same rendezvous and hibernate together. In the tropics the anaconda (Fig. 6), and perhaps other species of serpents, sometimes hibernate during the dry season of summer in the hardened mud of dried-up pools. It is by the power to hibernate that serpents survive during the winters of temperate climates, but they seem unable to withstand the extreme and long-continued cold of the arctic zone. There, serpents, and in-

FIG. 7.



NORTHERN RATTLESNAKE.

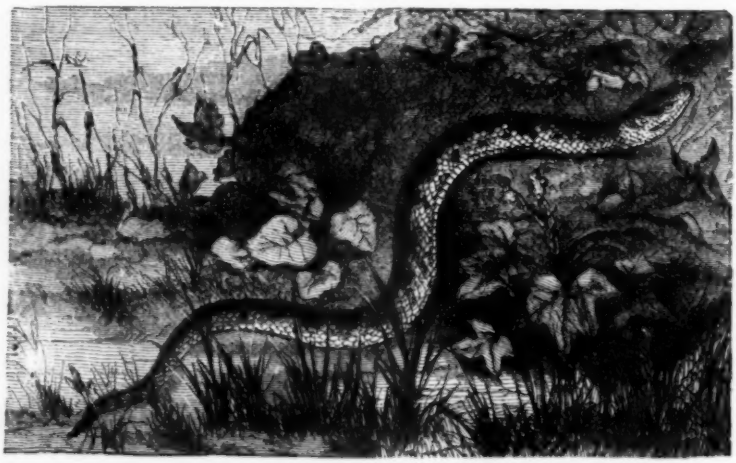
deed reptiles of all kinds, are rare, and frequently are entirely wanting. In the Falkland Islands, Terra del Fuego, and the mountains of Southern Patagonia, no serpents have been found. The persistence of vitality in serpents is extraordinary, and continues after great mutilations. They are said to have lived several days after removal of the head and viscera. One placed in a vacuum twenty-four hours still showed signs of sensibility; and, many hours after decapitation, a rattlesnake would plunge its headless trunk as in the usual act of striking.

In temperate climates serpents as a rule are less fierce than in the tropics. In North America the *Crotalidæ* comprise twelve species with rattles, and three species in which rattles are absent. Of the last named, the copperhead and moccasin snakes are well known. Of the first, the northern rattlesnake (Fig. 7) is familiar, and unpleasantly abundant in many parts of the country, but is nowhere fierce or inclined to attack. Fig. 8 is of the common viper, or adder of England and the Continent.

All the gigantic crushing species are found in regions of torrid temperature. Of these, the Guinea rock or fetich snake (Fig. 10) is allied to the family of pythons already noticed.

There too are the most terribly fierce of the venomous species, as the fer de lance (Fig. 11); the cobra (Fig. 12), sacred in India, the killing of which with some tribes is considered sacrilege; the haje or spitting-snake of Africa, a hooded species, and allied to the cobra, and the horned puff-adder (Fig. 13), whose poison is used to tip arrows by the South-African Bushmen.

FIG. 8.



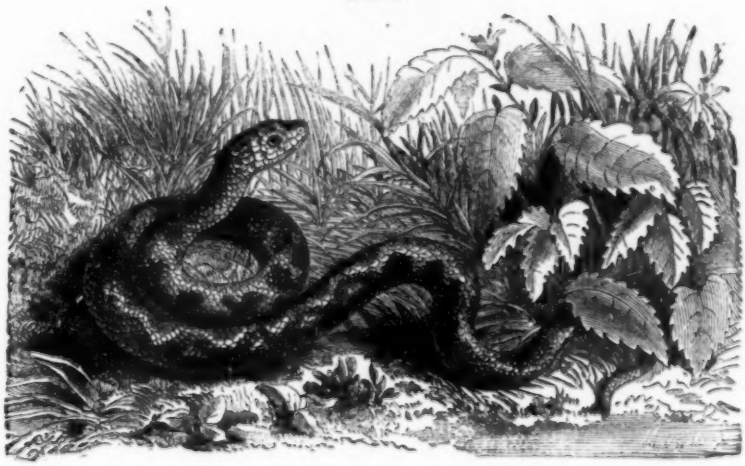
COMMON ADDER OF ENGLAND AND THE CONTINENT.—(Venomous.)

The mere recital of their names excites in one unpleasant sensations. Deaths from the bite of serpents in temperate regions which they infest are surprisingly rare. It is otherwise, however, in the tropics, and perhaps no country has so fearful a mortality from the bites of venomous snakes as India. In six provinces, which include Assam and Orissa, with a population of about 121,000,000, 11,416 deaths were reported in a single year. This is about one in every 10,000 of population, and this is only an approximation to the actual mortality, for many districts sent no returns. A majority of all the deaths from this cause was from cobras; yet this serpent, as ob-

served, is an object of veneration, and is regarded with peculiar deference. If found in their houses, as it frequently is, it must be petted, cared for, tenderly fed, and propitiated, for it is an object of worship, and occupies a high place in the mythology of the Hindoos. Indeed, the worship of serpents seems to have been widely adopted, and figures more or less in a vast number of the religions of the world. It is often referred to in the Scriptures, and is a subject of elaborate discussion in the profoundly learned and interesting volume of Ferguson, on "Tree and Serpent Worship."

We mentioned the fact that in most species serpents have but one fully-developed lung. Into the cavity of this the trachea or windpipe terminates, and it has been stated that they "in a manner swallow air." What takes place in the process of breathing appears to be this. Unlike mammals, serpents have no diaphragm, but by a movement of the ribs the cavity of the body is enlarged, and, a pressure being thus removed, the lung inflates and expands by the air passing into it. Another and opposite movement of the ribs expels the air, whence it appears that their process of breathing is essentially the same as in mammals. Nor are their lungs in structure essentially different. The air sacs or cells communicate with the principal pulmonary tube, but a vastly smaller surface is exposed to the inhaled air, and aëration of the blood is consequently extremely imperfect and incomplete.

FIG. 9.



SMALL VIPERINE SNAKE (*Tropidonotus Viperinus*).

Serpents are without proper organs of voice, the vibrating membranes being absent. The passage of air into and out of the lungs, if hurried and rapid, produces a hissing noise, the only voice possible to them, but which we fear makes less interesting their somewhat unprepossessing features.

A scale-like covering, which is fixed and immovable, covers the eye of the serpent, as shown in Fig. 4, and gives to it, as Prof. Nicholson vividly expresses it, the "peculiar, stony, unwinking stare" for which they are remarkable, and which, when they are enraged, becomes intensely fierce.

FIG. 10.

GUINEA ROCK-SNAKE.

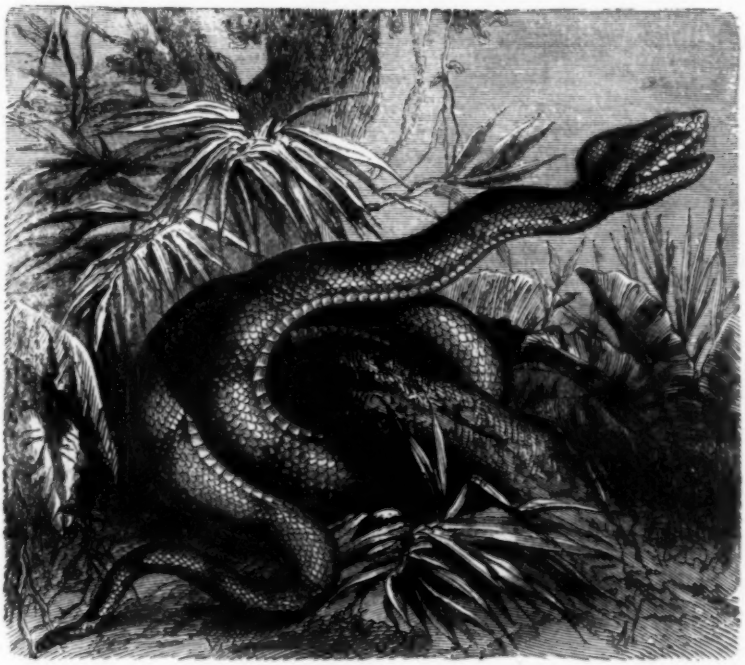
This covering is evidently transparent, as the animal distinguishes forms, but in the cast-off skin it is translucent only. Behind the eye-ball is a lachrymal gland, with a duct which conveys tears to the membranes of the eye. By this means they are kept moist. A conduit connects the eye-cavity with the olfactory opening, and, should the creature shed tears, it would be through that opening, not directly from its eyes.

In common with other animals, serpents have some habits and

instincts peculiar to themselves, which are directly related to the necessities of their being; but we are not aware that they display great sagacity, cunning, or wisdom. They are not fertile in devices, not especially artful, and the extreme simplicity and smallness of their brain indicate their low mental powers.

The entire tribe of serpents for the purposes of this paper may be divided into the venomous and non-venomous species. Of the non-venomous, we will pass, with one or two remarks, the interesting families of double walkers, and slow or blind worms (Fig. 14), types which are structurally intermediate between true serpents and lizards. The first of these derives its name from the fact that it can progress

FIG. 11.



FER DE LANCE.

with facility forward or backward; the second from the erroneous notion that it has no eyes. To this class belong the curious glass-snakes, so named from their fragility. Other non-venomous serpents comprise the inoffensive and harmless, and some of the most terrible species. Of these we have noticed the gigantic rock-snake or python of India, which attains a length of 30 feet. The Natal rock-snake is found 25 feet long. Of equal size is the boa-constrictor of tropical America, formerly an object of worship. The anaconda, or water-serpent, which frequents the rivers of Brazil, and watches for its prey along their banks, is sometimes more than 25 feet long. These are

among the most powerful of their kind, in whose folds man is helpless, and bones of goats and cattle are broken with a crash which, it is said, may be heard many rods. We turn from these, whose fearful presence we associate with the splendors of tropical forests, to species harmless and often serviceable to man, yet everywhere persecuted by him. Among these we find the beautiful ring and grass snakes of our gardens; the milk and striped or garter snake; the common adder (so called), but entirely harmless; the active black snake or racer, found nearly everywhere in the United States. More dreaded because more dangerous than the gigantic species mentioned, are the venom-

FIG. 12.

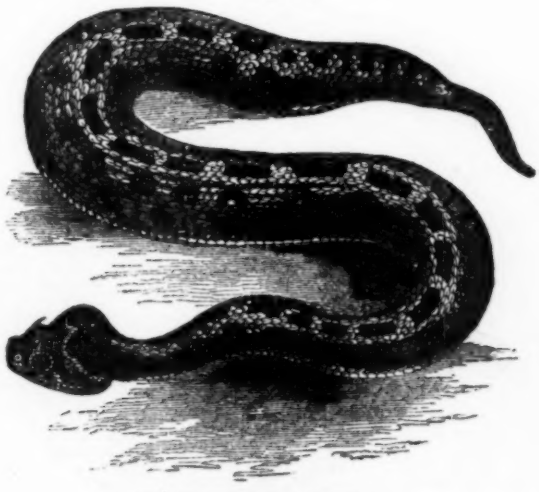
COBRA-DE-CAPELLO.

ous serpents, not powerful in strength or immense in size, but fierce in some cases, and in their attack deadly. The largest of these is said to be the bush-master, found in British Guiana, which, on the authority of Waterton, attains a length of fourteen feet. But the belted hamadryad of Burmah is often seen twelve to fourteen feet in length, and is a foot in circumference; and it is stated that specimens have been seen three fathoms (eighteen feet) long. If so, it is probably the largest known venomous serpent. This terrible creature feeds on other snakes, hence its scientific name, *Ophiophagus elaps*. Others, as the cobra and the rattlesnake, are relatively small, rarely attaining a length greater than six feet, usually not more than four feet.

But the distinguishing feature of venomous serpents is their poison fangs and glands, by which the fatal fluid is secreted. They kill by a stroke, or blow, which drives the fang into the flesh, and there discharges the venom. Some are intensely active and fierce, and will spring upon the traveler, as the fer de lance and the haje. Others, as the northern rattlesnake, seldom attack but rather retreat from man.

The fangs are in the upper jaw, as shown in Fig. 4. In a rattlesnake, four feet in length, they are about half an inch long. Behind them are the glands, which secrete the poisonous fluid, from five to ten drops of which have, in some cases, been obtained from a single fang. It is tasteless, and nearly colorless, and, on being dried up, leaves minute crystalline spicules, or scales. The venom of all the poisonous species of serpents appears to be essentially the same, but differs in intensity or virulence. The fang is perforated by a small canal in

FIG. 13.



THE HORNED PUFF-ADDER.

front of the usual pulp-cavity, through which the venom is discharged by pressure brought to bear upon the glands from the act of striking. A rattlesnake confined in a cage, when irritated, struck against the wire bars with its fangs, throwing the venom a distance of three feet. The fang usually lies flat, and partly hidden in the fleshy tissue, but is erected when needed for use; and it is only when erected that its connection with the venom-gland is so adjusted that the fluid may be thrown out.

The poison is always more or less dangerous to animal life. Cattle have died from a bite of the fer de lance in a few hours. Smaller animals die directly. Horses have been killed by rattlesnakes, and people bitten by them may die in a few minutes or in a few days, but

sometimes recover. If the poison is discharged into the arteries or veins, the vital functions directly fail, "the victim staggers, and falls from exhaustion—depressing gloom settles on the features—a cold sweat comes upon the face—and death at once supervenes." In such cases the blood is unchanged, and appears healthy; but, where the effect is not immediate, it undergoes change—"ceases to coagulate, the fibrine disappears, and the patient dies with ordinary symptoms of slow poisoning."

A multitude of remedies have been suggested for the bite of serpents; of these, ammonia and alcohol are prominent. Prof. Halfourd, of Australia, reported the recovery of seventeen out of twenty cases of severe bites, from the injection of a solution of ammonia into the veins. The free use of alcohol in some form has been stoutly advocated by many physicians, while others assert that patients have died from the poison even while intoxicated by the remedy. An exhaustive paper

FIG. 14.

BLIND OR SLOW WORM.

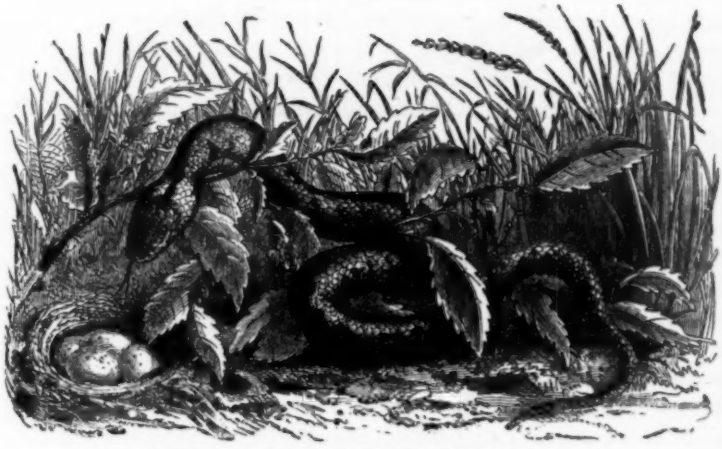
on rattlesnake-bites, and their remedy, by Dr. Mitchell, was published in No. 12 of the "Smithsonian Contributions to Knowledge," to which we are indebted for several interesting statements, and to which we refer our readers.

The conclusions of Dr. Fayrer, from his exhaustive experiments upon snake-poisoning in India, are, that most of the popular remedies are of little value, and he seems to differ somewhat from Prof. Halfourd. The celebrated snake-stones, which are said to "absorb and suck out the poison," he "believes are perfectly powerless to produce any such effect." He advises ligature to prevent, if possible, the passage of the poison into the circulation. Whiskey and ammonia are

useful as stimulants; but he found, by experiment, that neither liquor ammoniæ nor liquor potassæ destroys the poisonous properties of the venom, although mixed directly with it. Suction of the wound is good, but may be dangerous. Immediate cauterization of the wound, or removal of it by the knife, is indispensable.

It was found, by Dr. Gilman, that healthy, vigorous vegetables perish in a few hours on being inoculated with the venom of the rattlesnake. Others have found the same results, although Dr. Mitchell did not. Dr. Salisbury poisoned eight lilac and other bushes, the leaves of which above—*not below*—the point of inoculation withered in a few days. Terrible and virulent as this poison is, it undergoes decomposition in a short time, and becomes filled with forms of animal life and covered with fungi. It may, when fresh from the fang, be swallowed by the animal itself, or by man, without injury. Prof. Baird says: "I have myself (rather foolishly, I must confess) swallowed nearly the entire contents of one gland of a large rattlesnake;" but, if the animal be inoculated by its own venom, it speedily dies. Such, however, is not the case with the venom of the cobra, according to experiments made by Dr. Fayrer, who says: "I believe that it is

FIG. 15.



RING OR GRASS SNAKE, COMMON IN ENGLAND.

capable of absorption, through the mucous and serous membranes with which it is brought into contact. Placed on the conjunctiva of dogs, the symptoms of poisoning were rapidly developed." The same authority states that the cobra does not die from its own bite, or that of its kind, but that innocuous serpents are directly killed by it.

It is a singular fact that the *flesh* of animals killed by snake-poison may be eaten with impunity. The fowls killed by Dr. Fayrer were taken and eaten by the sweepers. But the blood of an animal killed by snake-venom is itself poisonous, and poisons the animal into which

it is injected. The authority just quoted says: "I have transmitted the poison through three animals, with fatal results."

The formation of rattles upon the tail of a rattlesnake is a curious phenomenon. The notion that one is developed each year is incorrect. Young ones have been known to have six or more; sometimes two or three appear in a single year. The number seldom exceeds fifteen. The skin of one that was six feet long, now in the Museum of the Long Island Historical Society of Brooklyn, has fourteen rattles. De Kay cited, in 1842, the *Clarion* newspaper, published at Bolton, New York, which stated that two men killed, in three days, in the town of Bolton, at Lake George, 1,104 rattlesnakes, some of which carried fifteen to twenty rattles. They were killed for their oil. The same author states, on the authority of the *Columbian Magazine* for November, 1786, that a rattlesnake was killed, having forty-four rattles, which seems an incredible number. The use of the rattles is a subject of discussion. They are evidently well developed—not rudimental merely—and the conclusion is irresistible that they are of service to the creature. We cannot suppose that organs which are constant in a class of animals, could have originated, if entirely useless and unserviceable to it. Prof. Aughey suggests that the whirring rattle is a call-note by the animal to its mate. That it was thus used on one occasion he was an eye-witness. Again, it may be used to terrify its enemies; or to paralyze its victims with fright, or to call assistance in danger. He says: "I once witnessed an attack by seven hogs on a rattlesnake. Immediately the snake rattled, and three others appeared; but the hogs were victorious."

The power of serpents to overcome birds by fascination is considered by most writers doubtful. But it cannot be questioned, we think, that birds sometimes become powerless in the presence of snakes. We once saw a cat-bird on a low branch with drooped wings, feathers erect, and mouth open, apparently breathing heavily, looking directly at the head of a black snake which was within fifteen inches of the head of the bird, and very slowly moving forward. A sharp blow on a board startled the snake, and seemed instantly to release the bird from its dream, when it flew away. Perhaps the able paper on "Hypnotism in Animals," by Prof. Czermak, published in THE POPULAR SCIENCE MONTHLY for September, 1873, may suggest a possible solution of this phenomenon.

All serpents are essentially oviparous; that is, the young are produced from eggs. Nevertheless, many species, including all the venomous ones, according to Cuvier, bring forth their young alive; but this is in consequence of the eggs being hatched before being laid. A boa-constrictor produced *both* eggs and living young in the Zoological Gardens at Amsterdam. The eggs of serpents are without a calcareous shell, and those of our common species are often exposed in turning the ground in fields and in gardens. The young are at once quite ac-

tive, and we have seen them when very young display the instinctive habits of their species.

The python coils around her eggs, and faithfully remains there during their two months of incubation; the temperature of her body rising, in one instance, to 96° Fahr. All this time she refuses food, "but appears feverish, and drinks water freely."

The time when serpents first appeared upon the globe is comparatively recent. No fossil remains of them have yet been discovered, until after the close of the Age of Reptiles. The oldest yet found were in the Eocene of the south of England. Prof. E. D. Cope first found them in the United States in the Eocene of New Jersey. They have been found also by Prof. Marsh in the Eocene of Wyoming. Prof. Cope discovered five new species during the past summer in the Miocene of Colorado, and has also obtained them from Post-Pliocene formations. So it appears that, during the whole of the Tertiary, serpents abounded, and the fact that in the Eocene they were so widely distributed suggests a much earlier origin for this order of reptiles. How numerous they may have been during periods subsequent to their advent is not easily determined. But, notwithstanding their abundance in the tropics, and in contiguous regions, it is probable that their period of greatest abundance, if not of greatest development, has passed. Civilization destroys them, or drives them to the swamps, the mountains, and the wilderness.

The number of species of snakes found in the State of New York is seventeen. Two of these are venomous, the rattlesnake and the viper. Sixteen species are named in Prof. Cook's catalogue for New Jersey, and that gentleman remarks: "All of them are of great value to the agriculturist, and the popular prejudice against them should be done away with." It should be more widely known and more often considered that snakes destroy immense numbers of animals which are detrimental to the interests of man, as rats, mice, insects, larvæ, and worms of various kinds. The fer de lance infests the sugar-plantations of some of the West India islands, not to destroy men, who fear it, but to obtain rats for food, which swarm there in incredible numbers. In the State of Maine are ten species of snakes, in Michigan fifteen species, and from Baird and Girard's catalogue, published in 1853, we learn that 119 species of North American serpents were at that time known and described.

In the older settled portions of the United States their numbers have diminished, and in the more thoroughly cultivated sections of New England, New York, New Jersey, and perhaps other States, their scarcity is a matter of common observation. Before persistent warfare, and amid conditions which are becoming more unfavorable to their habits of life, they will doubtless become fewer in number and species, and, in such regions, the period of their extinction may not be very remote.

THE THEORY OF MOLECULES.[1]

By Professor CLERK MAXWELL, F. R. S.

AN atom is a body which cannot be cut in two. A molecule is the smallest possible portion of a particular substance. No one has ever seen or handled a single molecule. Molecular science, therefore, is one of those branches of study which deal with things invisible and imperceptible by our senses, and which cannot be subjected to direct experiment.

The mind of man has perplexed itself with many hard questions. Is space infinite, and if so in what sense? Is the material world infinite in extent, and are all places within that extent equally full of matter? Do atoms exist, or is matter infinitely divisible?

The discussion of questions of this kind has been going on ever since men began to reason, and to each of us, as soon as we obtain the use of our faculties, the same old questions arise as fresh as ever. They form as essential a part of the science of the nineteenth century of our era, as of that of the fifth century before it.

We do not know much about the science organization of Thrace twenty-two centuries ago, or of the machinery then employed for diffusing an interest in physical research. There were men, however, in those days, who devoted their lives to the pursuit of knowledge with an ardor worthy of the most distinguished members of the British Association; and the lectures in which Democritus explained the atomic theory to his fellow-citizens of Abdera realized, not in golden opinions only, but in golden talents, a sum hardly equaled even in America.

To another very eminent philosopher, Anaxagoras, best known to the world as the teacher of Socrates, we are indebted for the most important service to the atomic theory, which, after its statement by Democritus, remained to be done. Anaxagoras, in fact, stated a theory which so exactly contradicts the atomic theory of Democritus that the truth or falsehood of the one theory implies the falsehood or truth of the other. The question of the existence or non-existence of atoms cannot be presented to us this evening with greater clearness than in the alternative theories of these two philosophers.

Take any portion of matter, say a drop of water, and observe its properties. Like every other portion of matter we have ever seen, it is divisible. Divide it in two, each portion appears to retain all the properties of the original drop, and among others that of being divisible. The parts are similar to the whole in every respect except in absolute size.

[1] Lecture delivered before the British Association at Bradford.

Now go on repeating the process of division till the separate portions of water are so small that we can no longer perceive or handle them. Still we have no doubt that the subdivision might be carried further, if our senses were more acute and our instruments more delicate. Thus far all are agreed, but now the question arises, Can this subdivision be repeated forever?

According to Democritus and the atomic school, we must answer in the negative. After a certain number of subdivisions, the drop would be divided into a number of parts each of which is incapable of further subdivision. We should thus, in imagination, arrive at the atom, which, as its name literally signifies, cannot be cut in two. This is the atomic doctrine of Democritus, Epicurus, and Lucretius, and, I may add, of your lecturer.

According to Anaxagoras, on the other hand, the parts into which the drop is divided are in all respects similar to the whole drop, the mere size of a body counting for nothing as regards the nature of its substance. Hence if the whole drop is divisible, so are its parts down to the minutest subdivisions, and that without end.

The essence of the doctrine of Anaxagoras is, that the parts of a body are in all respects similar to the whole. It was therefore called the doctrine of Homoiomereia. Anaxagoras did not of course assert this of the parts of organized bodies such as men and animals, but he maintained that those inorganic substances which appear to us homogeneous are really so, and that the universal experience of mankind testifies that every material body, without exception, is divisible.

The doctrine of atoms and that of homogeneity are thus in direct contradiction.

But we must now go on to molecules. Molecule is a modern word. It does not occur in Johnson's "Dictionary." The ideas it embodies are those belonging to modern chemistry.

A drop of water, to return to our former example, may be divided into a certain number, and no more, of portions similar to each other. Each of these the modern chemist calls a molecule of water. But it is by no means an atom, for it contains two different substances, oxygen and hydrogen, and by a certain process the molecule may be actually divided into two parts, one consisting of oxygen and the other of hydrogen. According to the received doctrine, in each molecule of water there are two molecules of hydrogen and one of oxygen. Whether these are or are not ultimate atoms I shall not attempt to decide.

We now see what a molecule is, as distinguished from an atom.

A molecule of a substance is a small body such that if, on the one hand, a number of similar molecules were assembled together they would form a mass of that substance, while on the other hand, if any portion of this molecule were removed, it would no longer be able, along with an assemblage of other molecules similarly treated, to make up a mass of the original substance.

Every substance, simple or compound, has its own molecule. If this molecule be divided, its parts are molecules of a different substance or substances from that of which the whole is a molecule. An atom, if there is such a thing, must be a molecule of an elementary substance. Since, therefore, every molecule is not an atom, but every atom is a molecule, I shall use the word molecule as the more general term.

I have no intention of taking up your time by expounding the doctrines of modern chemistry with respect to the molecules of different substances. It is not the special but the universal interest of molecular science which encourages me to address you. It is not because we happen to be chemists or physicists or specialists of any kind that we are attracted toward this centre of all material existence, but because we all belong to a race endowed with faculties which urge us on to search deep and ever deeper into the nature of things.

We find that now, as in the days of the earliest physical speculations, all physical researches appear to converge toward the same point, and every inquirer, as he looks forward into the dim region toward which the path of discovery is leading him, sees, each according to his sight, the vision of the same quest.

One may see the atom as a material point, invested and surrounded by potential forces. Another sees no garment of force, but only the bare and utter hardness of mere impenetrability.

But though many a speculator, as he has seen the vision recede before him into the innermost sanctuary of the inconceivably little, has had to confess that the quest was not for him, and though philosophers in every age have been exhorting each other to direct their minds to some more useful and attainable aim, each generation, from the earliest dawn of science to the present time, has contributed a due proportion of its ablest intellects to the quest of the ultimate atom.

Our business this evening is to describe some researches in molecular science, and in particular to place before you any definite information which has been obtained respecting the molecules themselves. The old atomic theory, as described by Lucretius and revived in modern times, asserts that the molecules of all bodies are in motion, even when the body itself appears to be at rest. These motions of molecules are, in the case of solid bodies, confined within so narrow a range that even with our best microscopes we cannot detect that they alter their places at all. In liquids and gases, however, the molecules are not confined within any definite limits, but work their way through the whole mass, even when that mass is not disturbed by any visible motion.

This process of diffusion, as it is called, which goes on in gases and liquids and even in some solids, can be subjected to experiment, and forms one of the most convincing proofs of the motion of molecules.

Now, the recent progress of molecular science began with the study of the mechanical effect of the impact of these moving molecules when they strike against any solid body. Of course these flying molecules must beat against whatever is placed among them, and the constant succession of these strokes is, according to our theory, the sole cause of what is called the pressure of air and other gases.

This appears to have been first suspected by Daniel Bernoulli, but he had not the means which we now have of verifying the theory. The same theory was afterward brought forward independently by Lesage, of Geneva, who, however, devoted most of his labor to the explanation of gravitation by the impact of atoms. Then Herapath, in his "Mathematical Physics," published in 1847, made a much more extensive application of the theory to gases; and Dr. Joule, whose absence from our meeting we must all regret, calculated the actual velocity of the molecules of hydrogen.

The further development of the theory is generally supposed to have been begun with a paper by Krönig, which does not, however, so far as I can see, contain any improvement on what had gone before. It seems, however, to have drawn the attention of Prof. Clausius to the subject, and to him we owe a very large part of what has been since accomplished.

We all know that air or any other gas placed in a vessel presses against the sides of the vessel, and against the surface of any body placed within it. On the kinetic theory this pressure is entirely due to the molecules striking against these surfaces, and thereby communicating to them a series of impulses which follow each other in such rapid succession that they produce an effect which cannot be distinguished from that of a continuous pressure.

If the velocity of the molecules is given, and the number varied, thence since each molecule, on an average, strikes the side of the vessel the same number of times, and with an impulse of the same magnitude, each will contribute an equal share to the whole pressure. The pressure in a vessel of given size is therefore proportional to the number of molecules in it, that is, to the quantity of gas in it.

This is the complete dynamical explanation of the fact discovered by Robert Boyle, that the pressure of air is proportional to its density. It shows also that, of different portions of gas forced into a vessel, each produces its own part of the pressure independently of the rest, and this whether these portions be of the same gas or not.

Let us next suppose that the velocity of the molecules is increased. Each molecule will now strike the sides of the vessel a greater number of times in a second, but besides this, the impulse of each blow will be increased in the same proportion, so that the part of the pressure due to each molecule will vary as the *square* of the velocity. Now, the increase of the square of velocity corresponds, in our theory, to a rise of temperature, and in this way we can explain the effect of

warming the gas, and also the law discovered by Charles, that the proportional expansion of all gases between given temperatures is the same.

The dynamical theory also tells us what will happen if molecules of different masses are allowed to knock about together. The greater masses will go slower than the smaller ones, so that, on an average, every molecule, great or small, will have the same energy of motion.

The proof of this dynamical theorem, in which I claim the priority, has recently been greatly developed and improved by Dr. Ludwig Boltzmann. The most important consequence which flows from it is, that a cubic centimetre of every gas at standard temperature and pressure contains the same number of molecules. This is the dynamical explanation of Gay-Lussac's law of the equivalent volumes of gases. But we must now descend to particulars, and calculate the actual velocity of a molecule of hydrogen.

A cubic centimetre of hydrogen, at the temperature of melting ice and at a pressure of one atmosphere, weighs 0.00008954 gramme. We have to find at what rate this small mass must move (whether altogether or in separate molecules makes no difference) so as to produce the observed pressure on the sides of the cubic centimetre. This is the calculation which was first made by Dr. Joule, and the result is 1,859 metres per second. This is what we are accustomed to call a great velocity. It is greater than any velocity obtained in artillery practice. The velocity of other gases is less, as you will see by the table, but in all cases it is very great as compared with that of bullets.

We have now to conceive the molecules of the air in this hall flying about in all directions, at a rate of about seventeen miles in a minute.

If all these molecules were flying in the same direction, they would constitute a wind blowing at the rate of seventeen miles a minute, and the only wind which approaches this velocity is that which proceeds from the mouth of a cannon. How, then, are you and I able to stand here? Only because the molecules happen to be flying in different directions, so that those which strike against our backs enable us to support the storm which is beating against our faces. Indeed, if this molecular bombardment were to cease, even for an instant, our veins would swell, our breath would leave us, and we should, literally, expire. But it is not only against us or against the walls of the room that the molecules are striking. Consider the immense number of them, and the fact that they are flying in every possible direction, and you will see that they cannot avoid striking each other. Every time that two molecules come into collision, the paths of both are changed, and they go off in new directions. Thus each molecule is continually getting its course altered, so that in spite of its great velocity it may be a long time before it reaches any great distance from the point at which it set out.

I have here a bottle containing ammonia. Ammonia is a gas which you can recognize by its smell. Its molecules have a velocity of six hundred metres per second, so that, if their course had not been interrupted by striking against the molecules of air in the hall, every one in the most distant gallery would have smelt ammonia before I was able to pronounce the name of the gas. But, instead of this, each molecule of ammonia is so jostled about by the molecules of air, that it is sometimes going one way and sometimes another. It is like a hare which is always doubling, and, though it goes a great pace, it makes very little progress. Nevertheless, the smell of ammonia is now beginning to be perceptible at some distance from the bottle. The gas does diffuse itself through the air, though the process is a slow one, and, if we could close up every opening of this hall so as to make it air-tight, and leave every thing to itself for some weeks, the ammonia would become uniformly mixed through every part of the air in the hall.

This property of gases, that they diffuse through each other, was first remarked by Priestley. Dalton showed that it takes place quite independently of any chemical action between the inter-diffusing gases. Graham, whose researches were especially directed toward those phenomena which seem to throw light on molecular motions, made a careful study of diffusion, and obtained the first results from which the rate of diffusion can be calculated.

Still more recently, the rates of diffusion of gases into each other have been measured with great precision by Prof. Loschmidt, of Vienna.

He placed the two gases in two similar vertical tubes, the lighter gas being placed above the heavier, so as to avoid the formation of currents. He then opened a sliding-valve, so as to make the two tubes into one, and, after leaving the gases to themselves for an hour or so, he shut the valve, and determined how much of each gas had diffused into the other.

As most gases are invisible, I shall exhibit gaseous diffusion to you by means of two gases, ammonia and hydrochloric acid, which, when they meet, form a solid product. The ammonia, being the lighter gas, is placed above the hydrochloric acid, with a stratum of air between, but you will soon see that the gases can diffuse through this stratum of air, and produce a cloud of white smoke when they meet. During the whole of this process, no currents or any other visible motion can be detected. Every part of the vessel appears as calm as a jar of undisturbed air.

But, according to our theory, the same kind of motion is going on in calm air as in the inter-diffusing gases, the only difference being that we can trace the molecules from one place to another more easily when they are of a different nature from those through which they are diffusing.

If we wish to form a mental representation of what is going on among the molecules in calm air, we cannot do better than observe a swarm of bees, when every individual bee is flying furiously, first in one direction, and then in another, while the swarm, as a whole, either remains at rest, or sails slowly through the air.

In certain seasons, swarms of bees are apt to fly off to a great distance, and the owners, in order to identify their property when they find them on other people's ground, sometimes throw handfuls of flour at the swarm. Now, let us suppose that the flour thrown at the flying swarm has whitened those bees only which happened to be in the lower half of the swarm, leaving those in the upper half free from flour.

If the bees still go on flying hither and thither in an irregular manner, the floury bees will be found in continually increasing proportions in the upper part of the swarm, till they have become equally diffused through every part of it. But the reason of this diffusion is not because the bees were marked with flour, but because they are flying about. The only effect of the marking is to enable us to identify certain bees.

We have no means of marking a select number of molecules of air, so as to trace them after they have become diffused among others, but we may communicate to them some property by which we may obtain evidence of their diffusion.

For instance, if an horizontal stratum of air is moving horizontally, molecules diffusing out of this stratum, into those above and below, will carry their horizontal motion with them, and so tend to communicate motion to the neighboring strata, while molecules diffusing out of the neighboring strata into the moving one will tend to bring it to rest. The action between the strata is somewhat like that of two rough surfaces, one of which slides over the other, rubbing on it. Friction is the name given to this action between solid bodies; in the case of fluids it is called internal friction or viscosity.

It is in fact only another kind of diffusion—a lateral diffusion of momentum, and its amount can be calculated from data derived from observations of the first kind of diffusion, that of matter. The comparative values of the viscosity of different gases were determined by Graham in his researches on the transpiration of gases through long, narrow tubes, and their absolute values have been deduced from experiments on the oscillation of disks by Oscar Meyer and myself.

Another way of tracing the diffusion of molecules through calm air is to heat the upper stratum of the air in a vessel, and so observe the rate at which this heat is communicated to the lower strata. This, in fact, is a third kind of diffusion—that of energy, and the rate at which it must take place was calculated from data derived from experiments on viscosity before any direct experiments on the conduction of heat had been made. Prof. Stefan, of Vienna, has recently, by a very delicate method, succeeded in determining the conductivity of

air, and he finds it, as he tells us, in striking agreement with the value predicted by the theory.

All these three kinds of diffusion—the diffusion of matter, of momentum, and of energy—are carried on by the motion of the molecules. The greater the velocity of the molecules, and the farther they travel before their paths are altered by collision with other molecules, the more rapid will be the diffusion. Now, we know already the velocity of the molecules, and therefore by experiments on diffusion we can determine how far, on an average, a molecule travels without striking another. Prof. Clausius, of Bonn, who first gave us precise ideas about the motion of agitation of molecules, calls this distance the mean path of a molecule. I have calculated, from Prof. Loschmidt's diffusion experiments, the mean path of the molecules of four well-known gases. The average distance traveled by a molecule between one collision and another is given in the table. It is a very small distance, quite imperceptible to us even with our best microscopes. Roughly speaking, it is about the tenth part of the length of a wave of light, which you know is a very small quantity. Of course the time spent on so short a path by such swift molecules must be very small. I have calculated the number of collisions which each must undergo in a second. They are given in the table, and are reckoned by thousands of millions. No wonder that the traveling power of the swiftest molecule is but small, when its course is completely changed thousands of millions of times in a second.

The three kinds of diffusion also take place in liquids, but the relation between the rates at which they take place is not so simple as in the case of gases. The dynamical theory of liquids is not so well understood as that of gases, but the principal difference between a gas and a liquid seems to be that, in a gas each molecule spends the greater part of its time in describing its free path, and is for a very small portion of its time engaged in encounters with other molecules, whereas in a liquid the molecule has hardly any free path, and is always in a state of close encounter with other molecules.

Hence, in a liquid, the diffusion of motion from one molecule to another takes place much more rapidly than the diffusion of the molecules themselves, for the same reason that it is more expeditious in a dense crowd to pass on a letter from hand to hand than to give it to a special messenger to work his way through the crowd. I have here a jar, the lower part of which contains a solution of copper sulphate, while the upper part contains pure water. It has been standing here since Friday, and you see how little progress the blue liquid has made in diffusing itself through the water above. The rate of diffusion of a solution of sugar has been carefully observed by Voit. Comparing his results with those of Loschmidt on gases, we find that about as much diffusion takes place in a second in gases as requires a day in liquids.

The rate of diffusion of momentum is also slower in liquids than

in gases, but by no means in the same proportion. The same amount of motion takes about ten times as long to subside in water as in air, as you will see by what takes place when I stir these two jars, one containing water and the other air. There is still less difference between the rates at which a rise of temperature is propagated through a liquid and through a gas.

In solids the molecules are still in motion, but their motions are confined within very narrow limits. Hence, the diffusion of matter does not take place in solid bodies, though that of motion and heat takes place very freely. Nevertheless, certain liquids can diffuse through colloid solids, such as jelly and gum, and hydrogen can make its way through iron and palladium.

We have no time to do more than mention that most wonderful molecular motion which is called electrolysis. Here is an electric current passing through acidulated water, and causing oxygen to appear at one electrode, and hydrogen at the other. In the space between, the water is perfectly calm, and yet two opposite currents of oxygen and of hydrogen must be passing through it. The physical theory of this process has been studied by Clausius, who has given reasons for asserting that in ordinary water the molecules are not only moving, but every now and then striking each other with such violence that the oxygen and hydrogen of the molecules part company, and dance about through the crowd, seeking partners which have become dissociated in the same way. In ordinary water these exchanges produce, on the whole, no observable effect, but no sooner does the electromotive force begin to act, than it exerts its guiding influence on the unattached molecules, and bends the course of each toward its proper electrode, till the moment when, meeting with an unappropriated molecule of the opposite kind, it enters again into a more or less permanent union with it till it is again dissociated by another shock. Electrolysis, therefore, is a kind of diffusion assisted by electromotive force.

Another branch of molecular science is that which relates to the exchange of molecules between a liquid and a gas. It includes the theory of evaporation and condensation, in which the gas in question is the vapor of the liquid, and also the theory of the absorption of a gas by a liquid of a different substance. The researches of Dr. Andrews on the relations between the liquid and the gaseous state have shown us that, though the statements in our own elementary text-books may be so neatly expressed that they appear almost self-evident, their true interpretation may involve some principle so profound that, till the right man has laid hold of it, no one ever suspects that any thing is left to be discovered.

These, then, are, some of the fields from which the data of molecular science are gathered. We may divide the ultimate results into three ranks, according to the completeness of our knowledge of them.

To the first rank belong the relative masses of the molecules of different gases, and their velocities in metres per second. These data are obtained from experiments on the pressure and density of gases, and are known to a high degree of precision.

In the second rank we must place the relative size of the molecules of different gases, the length of their mean paths, and the number of collisions in a second. These quantities are deduced from experiments on the three kinds of diffusion. Their received values must be regarded as rough approximations till the methods of experimenting are greatly improved.

There is another set of quantities which we must place in the third rank, because our knowledge of them is neither precise, as in the first rank, nor approximate, as in the second, but is only as yet of the nature of a probable conjecture. These are the absolute mass of a molecule, its absolute diameter, and the number of molecules in a cubic centimetre. We know the relative masses of different molecules with great accuracy, and we know their relative diameters approximately. From these we can deduce the relative densities of the molecules themselves. So far we are on firm ground.

The great resistance of liquids to compression makes it probable that their molecules must be at about the same distance from each other as that at which two molecules of the same substance in the gaseous form act on each other during an encounter. This conjecture has been put to the test by Lorenz Meyer, who has compared the densities of different liquids with the calculated relative densities of the molecules of their vapors, and has found a remarkable correspondence between them.

Now, Loschmidt has deduced from the dynamical theory the following remarkable proportion: As the volume of a gas is to the combined volume of all the molecules contained in it, so is the mean path of a molecule to one-eighth of the diameter of a molecule.

Assuming that the volume of the substance, when reduced to the liquid form, is not much greater than the combined volume of the molecules, we obtain from this proportion the diameter of a molecule. In this way Loschmidt, in 1865, made the first estimate of the diameter of a molecule. Independently of him and of each other, Mr. Stoney in 1868, and Sir W. Thomson, in 1870, published results of a similar kind, those of Thomson being deduced not only in this way, but from considerations derived from the thickness of soap-bubbles, and from the electric properties of metals.

According to the table, which I have calculated from Loschmidt's data, the size of the molecules of hydrogen is such that about two million of them in a row would occupy a millimetre, and a million million million million of them would weigh between four and five grammes!

In a cubic centimetre of any gas at standard pressure and tem-

perature, there are about nineteen million million million molecules. All these numbers of the third rank are, I need not tell you, to be regarded as at present conjectural. In order to warrant us in putting any confidence in numbers obtained in this way, we should have to compare together a greater number of independent data than we have as yet obtained, and to show that they lead to consistent results.

Thus far, we have been considering molecular science as an inquiry into natural phenomena. But, though the professed aim of all scientific work is to unravel the secrets of Nature, it has another effect, not less valuable, on the mind of the worker. It leaves him in possession of methods which nothing but scientific work could have led him to invent, and it places him in a position from which many regions of Nature, besides that which he has been studying, appear under a new aspect. The study of molecules has developed a method of its own, and it has also opened up new views of Nature.

When Lucretius wishes us to form a mental representation of the motion of atoms, he tells us to look at a sunbeam shining through a darkened room (the same instrument of research by which Dr. Tyndall makes visible to us the dust we breathe), and to observe the motes which chase each other in all directions through it. This motion of the visible motes, he tells us, is but a result of the far more complicated motion of the invisible atoms which knock the motes about. In his dream of Nature, as Tennyson tells us, he

> "saw the flaring atom-streams
> And torrents of her myriad universe,
> Running along the illimitable inane,
> Fly on to clash together again, and make
> Another and another frame of things
> Forever."

And it is no wonder that he should have attempted to burst the bonds of Fate by making his atoms deviate from their courses at quite uncertain times and places, thus attributing to them a kind of irrational free-will, which on his materialistic theory is the only explanation of that power of voluntary action of which we ourselves are conscious.

As long as we have to deal with only two molecules, and have all the data given us, we can calculate the result of their encounter; but when we have to deal with millions of molecules, each of which has millions of encounters in a second, the complexity of the problem seems to shut out all hope of a legitimate solution.

The modern atomists have therefore adopted a method which is, I believe, new in the department of mathematical physics, though it has long been in use in the section of statistics. When the working members of Section F get hold of a report of the census, or any other document containing the numerical data of Economic and Social Science, they begin by distributing the whole population into groups, according to age, income-tax, education, religious belief, or criminal convictions.

The number of individuals is far too great to allow of their tracing the history of each separately, so that, in order to reduce their labor within human limits, they concentrate their attention on a small number of artificial groups. The varying number of individuals in each group, and not the varying state of each individual, is the primary datum from which they work.

This, of course, is not the only method of studying human nature. We may observe the conduct of individual men and compare it with that conduct which their previous character, and their present circumstances, according to the best existing theory, would lead us to expect. Those who practise this method endeavor to improve their knowledge of the elements of human nature in much the same way as an astronomer corrects the elements of a planet by comparing its actual position with that deduced from the received elements. The study of human nature by parents and school-masters, by historians and statesmen, is therefore to be distinguished from that carried on by registrars and tabulators, and by those statesmen who put their faith in figures. The one may be called the historical, and the other the statistical method.

The equations of dynamics completely express the laws of the historical method as applied to matter, but the application of these equations implies a perfect knowledge of all the data. But the smallest portion of matter which we can subject to experiment consists of millions of molecules, not one of which ever becomes individually sensible to us. We cannot, therefore, ascertain the actual motion of any one of these molecules, so that we are obliged to abandon the strict historical method, and to adopt the statistical method of dealing with large groups of molecules.

The data of the statistical method as applied to molecular science are the sums of large numbers of molecular quantities. In studying the relations between quantities of this kind, we meet with a new kind of regularity, the regularity of averages, which we can depend upon quite sufficiently for all practical purposes, but which can make no claim to that character of absolute precision which belongs to the laws of abstract dynamics.

Thus molecular science teaches us that our experiments can never give us any thing more than statistical information, and that no law deduced from them can pretend to absolute precision. But, when we pass from the contemplation of our experiments to that of the molecules themselves, we leave the world of chance and change, and enter a region where every thing is certain and immutable.

The molecules are conformed to a constant type with a precision which is not to be found in the sensible properties of the bodies which they constitute. In the first place, the mass of each individual molecule, and all its other properties, are absolutely unalterable. In the second place, the properties of all molecules of the same kind are absolutely identical.

Let us consider the properties of two kinds of molecules, those of oxygen and those of hydrogen.

We can procure specimens of oxygen from very different sources—from the air, from water, from rocks of every geological epoch. The history of these specimens has been very different, and, if, during thousands of years, difference of circumstances could produce difference of properties, these specimens of oxygen would show it.

In like manner we may procure hydrogen from water, from coal, or, as Graham did, from meteoric iron. Take two litres of any specimen of hydrogen, it will combine with exactly one litre of any specimen of oxygen, and will form exactly two litres of the vapor of water.

Now, if, during the whole previous history of either specimen, whether imprisoned in the rocks, flowing in the sea, or careering through unknown regions with the meteorites, any modification of the molecules had taken place, these relations would no longer be preserved.

But we have another and an entirely different method of comparing the properties of molecules. The molecule, though indestructible, is not a hard, rigid body, but is capable of internal movements, and when these are excited it emits rays, the wave-length of which is a measure of the time of vibration of the molecule.

By means of the spectroscope the wave-lengths of different kinds of light may be computed to within one ten-thousandth part. In this way it has been ascertained, not only that molecules taken from every specimen of hydrogen in our laboratories have the same set of periods of vibration, but that light, having the same set of periods of vibration, is emitted from the sun and from the fixed stars.

We are thus assured that molecules of the same nature as those of our hydrogen exist in those distant regions, or at least did exist when the light by which we see them was emitted.

From a comparison of the dimensions of the buildings of the Egyptians with those of the Greeks, it appears that they have a common measure. Hence, even if no ancient author had recorded the fact that the two nations employed the same cubit as a standard of length, we might prove it from the buildings themselves. We should also be justified in asserting that at some time or other a material standard of length must have been carried from one country to the other, or that both countries had obtained their standards from a common source.

But in the heavens we discover by their light, and by their light alone, stars so distant from each other, that no material thing can ever have passed from one to another; and yet this light, which is to us the sole evidence of the existence of these distant worlds, tells us also that each of them is built up of molecules of the same kinds as those which we find on earth. A molecule of hydrogen, for example, whether

in Sirius or in Arcturus, executes its vibrations in precisely the same time.

Each molecule, therefore, throughout the universe, bears impressed on it the stamp of a metric system as distinctly as does the metre of the Archives of Paris, or the double royal cubit of the Temple of Karnac.

No theory of evolution can be formed to account for the similarity of molecules, for evolution necessarily implies continuous change, and the molecule is incapable of growth or decay, of generation or destruction.

None of the processes of Nature, since the time when Nature began, have produced the slightest difference in the properties of any molecule. We are therefore unable to ascribe either the existence of the molecules, or the identity of their properties, to the operation of any of the causes which we call natural.

On the other hand, the exact equality of each molecule to all others of the same kind gives it, as Sir John Herschel has well said, the essential character of a manufactured article, and precludes the idea of its being eternal and self-existent.

Thus we have been led, along a strictly scientific path, very near to the point at which Science must stop. Not that Science is debarred from studying the internal mechanism of a molecule which she cannot take to pieces, any more than from investigating an organism which she cannot put together. But, in tracing back the history of matter, Science is arrested when she assures herself, on the one hand, that the molecule has been made, and on the other that it has not been made by any of the processes we call natural.

Science is incompetent to reason upon the creation of matter itself out of nothing. We have reached the utmost limit of our thinking faculties when we have admitted that because matter cannot be eternal and self-existent it must have been created.

It is only when we contemplate, not matter in itself, but the form in which it actually exists, that our mind finds something on which it can lay hold.

That matter, as such, should have certain fundamental properties—that it should exist in space and be capable of motion, that its motion should be persistent, and so on, are truths which may, for any thing we know, be of the kind which metaphysicians call necessary. We may use our knowledge of such truths for purposes of deduction, but we have no data for speculating as to their origin.

But that there should be exactly so much matter and no more in every molecule of hydrogen is a fact of a very different order. We have here a particular distribution of matter—a *collocation*—to use the expression of Dr. Chalmers, of things which we have no difficulty in imagining to have been arranged otherwise.

The form and dimensions of the orbits of the planets, for instance,

are not determined by any law of Nature, but depend upon a particular collocation of matter. The same is the case with respect to the size of the earth, from which the standard of what is called the metrical system has been derived. But these astronomical and terrestrial magnitudes are far inferior in scientific importance to that most fundamental of all standards which forms the base of the molecular system. Natural causes, as we know, are at work, which tend to modify, if they do not at length destroy, all the arrangements and dimensions of the earth and the whole solar system. But though in the course of ages catastrophes have occurred, and may yet occur, in the heavens, though ancient systems may be dissolved and new systems evolved out of their ruins, the molecules out of which these systems are built—the foundation-stones of the material universe—remain unbroken and unworn.

They continue this day as they were created, perfect in number, and measure, and weight, and, from the ineffaceable characters impressed on them, we may learn that those aspirations after accuracy in measurement, truth in statement, and justice in action, which we reckon among our noblest attributes as men, are ours, because they are essential constituents of the image of Him who in the beginning created, not only the heaven and the earth, but the materials of which heaven and earth consist.

TABLE OF MOLECULAR DATA.

		Hydrogen.	Oxygen.	Carbonic Oxide.	Carbonic Acid.
Rank I.—	Mass of molecule (hydrogen = 1)	1	16	14	22
	Velocity (of mean square), metres per second at 0° C.	1,859	465	497	396
Rank II.—	Mean path, tenth-metres.	965	560	482	379
	Collisions in a second (millions).	17,750	7,646	9,489	9,720
Rank III.—	Diameter, tenth-metre.	5.8	7.6	8.3	9.3
	Mass, twenty-fifth grammes.	46	736	644	1,012

TABLE OF DIFFUSION: $\frac{(\text{centimetre})^2}{\text{second}}$ measure.

	Calculated.	Observed.	
H & O.....	0.7086	0.7214	Diffusion of matter observed by Loschmidt.
H & CO	0.6519	0.6422	
H & CO^2....	0.5575	0.5558	
O & CO	0.1807	0.1802	
O & CO^2 ...	0.1427	0.1409	
CO & CO^2....	0.1386	0.1406	
H	1.2990	1.49	Diffusion of momentum. Graham and Meyer.
O	0.1884	0.213	
CO	0.1748	0.212	
CO^2	0.1087	0.117	
Air	.....	0.256	Diffusion of temperature observed by Stefan.
Copper	.....	1.077	
Iron	.....	0.183	
Cane-sugar in water	0.00000365		Voit.
Diffusion in a day	0.3114		
Salt in water.....	0.00000116		Fick.

PAST AND FUTURE OF A CONSTELLATION.

By CAMILLE FLAMMARION.

TRANSLATED FROM THE FRENCH, BY J. FITZGERALD, A. M.

THE notions hitherto entertained as to the stars and the heavens are destined to undergo a complete revolution. There are *no fixed stars*. Each one of those distant suns, flaming in infinitude, is swept along in a stupendous movement which the imagination can hardly conceive. Notwithstanding the countless millions of miles of space between them and us, making them appear to us only as luminous points, whereas they are as great as our own sun, and thousands and millions of times greater than the earth, still, by means of the telescope and computation, astronomers have been able to come at them, and to demonstrate that they are all moving in every possible direction. The heavens are no longer motionless, nor can the constellations any longer be regarded as the symbol of the unchangeable. Take, for instance, Ursa Major, or the Great Bear, the first of the constellations to be observed and named. Who is there that has not taken that figure as the enduring symbol of the preëstablished harmony, the unalterable duration of the firmament? Well, that ancient constellation will be destroyed. Each one of the stars which constitute it is endowed with a movement of its own. The result is that, in course of time, the form of Ursa Major will be changed. It now somewhat resembles in outline a wagon, and hence its popular title everywhere of car, or wain, while the learned have given it the name of the Bear, that being the only animal known to the ancients as living in polar regions. As every one knows, the four stars arranged in the form of a quadrilateral are supposed to represent the four wheels, and the three stars in the front of the figure three horses. But the proper movement of the separate stars will alter this arrangement: it will bring the foremost horse to a point back of where he now is, while the other two will move onward. As for the two hinder wheels, they will proceed in contrary directions. When we know the annual value of the displacement of each of these seven stars, we can calculate their future relative positions. This I have done, and I here lay before the reader the curious results of my calculations.

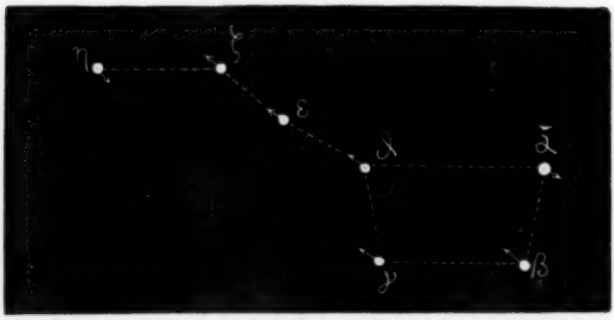
In order to get an exact account of the difference in the form of this constellation, which will be observable at a given time, let us first portray its present state.

The Arabs gave these seven famous stars names which are sometimes applied to them still. Beginning with the hind off-wheel, and then taking in the order indicated by the Greek letters (β, γ, δ, ε, ζ, η) the other wheels and the horses, the Arab names are as follows: Dubhe,

Merak, Phegda, Megrez, Alioth, Mizar, and Ackaïr. The last is the name given to the foremost horse. Persons possessed of good visual powers can discern above the second horse, Mizar, a small star which is called *the Postilion.* But these names are seldom employed in our times, the usual custom being to designate the seven principal stars of Ursa Major by the first seven letters of the Greek alphabet, as shown in the diagram. All these stars are of the second magnitude, except Delta (Fig. 1), which is of the third.

In the diagram, the arrows show the mean direction in which each of the seven stars moves. It will be seen that, of the seven, the first

FIG. 1.



THE SEVEN STARS OF URSA MAJOR IN THEIR PRESENT POSITIONS.

and the last, Alpha and Eta, are moving in a direction contrary to that of the other five. It must be added that they have not all the same velocity. Eta, for example, moves rapidly; Epsilon slowly; and so on with the others.

The quantity of their annual proper movements in right ascension, and in polar distance, is given for each of the seven stars in the following table:

	R. A.	P. D.
Alpha	(a) — 0″.013	+ 0″.09
Beta	(β) + 0″.015	— 0″.03
Gamma	(γ) + 0″.016	+ 0″.02
Delta	(δ) + 0″.019	+ 0″.06
Epsilon	(ε) + 0″.017	+ 0″.06
Zeta	(ζ) + 0″.020	+ 0″.04
Eta	(η) — 0″.033	+ 0″.03

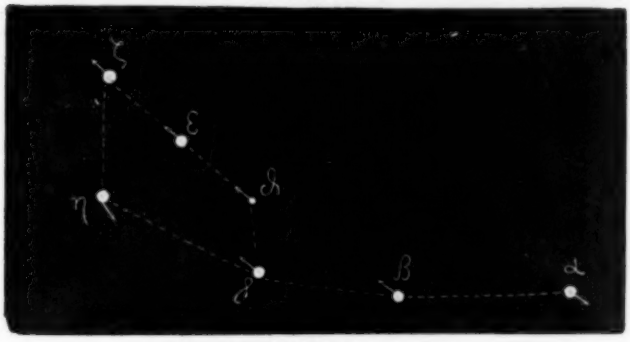
In consequence of these proper movements, the relative distances between the stars of the constellation are ever changing. But, as this change only amounts to a few seconds in a century, many centuries must elapse before it is perceptible to the naked eye. Our human generations, our dynasties, nay, even our nations, are not sufficiently long-lived to measure this change.

We have here to deal with astronomical quantities, and, to appre-

ciate these, we must choose terms which correspond with them. The earth has but one measure of time that can be employed here, viz., its great year, the precession of its equinoxes—a slow revolution of the globe, which is completed in more than 25,000 years. A period like that might serve as a basis of measurement in geology and in sidereal astronomy. Taking, then, four of these periods—in round numbers 100,000 years—we ought, after that length of time, to have a sensible difference in the aspect of the heavens; and, in fact, on computation, I find that in this interval—which in the history of the stars is but a brief span—all the present constellations will be broken up.

In Fig. 2 I give the geometrical results of my calculations as to the proper movements of the stars in Ursa Major. Here is to be seen the shape which that constellation will wear 100,000 years hence. There is nothing like a wagon in this new figure. Alpha has moved downward and ranged itself on the right of Beta, and both of these lie on one line with Gamma, and even with Eta. Delta, Epsilon, and Zeta,

FIG. 2.



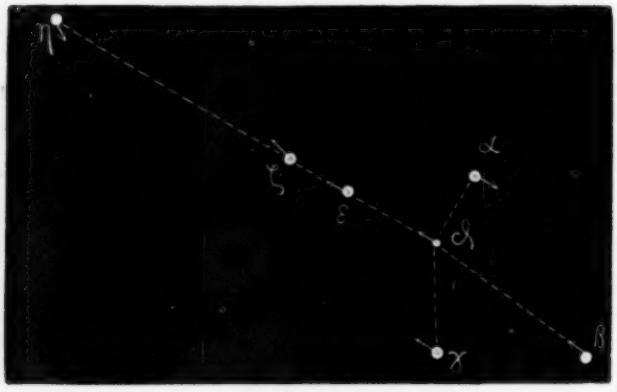
URSA MAJOR 100,000 YEARS HENCE.

are seen ranged on another line. If, in that distant epoch, the languages of terrestrial man shall still give to this constellation the title of the Wain, no one will be able to understand why. In considering what a mighty change it is destined to undergo in the future, the question arises, How long has it worn the shape in which it is familiar to us, and how did it look ages ago? One hundred thousand years ago there were, as yet, in all probability, no human beings on the earth, and the antediluvian monsters were the only creatures that could then view the starry sky.

Still, some of the older planets—Mars, Jupiter, Saturn, Uranus, and Neptune—were, no doubt, inhabited even then; and, as the heavens have the same appearance when viewed from them as from the earth, the dwellers in those worlds saw Ursa Major as it appeared in those days. All that we have to do, in order to find the position of each of the seven stars 100,000 years ago, is to move them back from their

present positions as far as they were moved forward in our second diagram. The result is a figure having no resemblance to either of the others. It is a sort of cross, with Beta at the point of intersection, Alpha marking the extremity of the left arm, and Gamma that of the right; Beta the top, Epsilon, Zeta, and Eta, the stem. Eta was, properly speaking, not yet in association with the other six. For the rest, on analyzing the movement of these stars, we see that five of them, Beta, Gamma, Delta, Epsilon, and Zeta, are associated together by a common tie. They are a group of friends: they move on with one accord, and, as will be seen, maintain the same relative position to one another. Alpha and Eta are only intruders, and, though they happen just at present to be with the group, they really have nothing to do with it. Look at Fig. 2: Alpha, which is ever

FIG. 3.



URSA MAJOR 100,000 YEARS AGO.

moving toward the right, will, in time, quit the group for good. On the other hand, Fig. 3 shows Eta coming in on the left; previously that star had no relation at all to the five.

The remarks just made with regard to the secular transformation of Ursa Major might be applied to all the other constellations. We have selected that one, because it is the best known of all, and one of the most characteristic. To sum up: we find that a knowledge of the proper movements of the stars completely transforms our common notions about the fixity of the heavens. The stars move in all directions through the endless realms of space, and as the aspect of the heavens changes, so does the constitution of the universe also change from age to age, undergoing innumerable metamorphoses.—*Revue Scientifique.*

REPLIES TO CRITICISMS.

By HERBERT SPENCER.

I.

WHEN made by a competent reader, an objection usually implies one of two things. Either the statement to which he demurs is wholly or partially untrue; or, if true, it is presented in such a way as to permit misapprehensions. A need for some change or addition is in any case shown.

Not recognizing the errors alleged, but thinking rather that misapprehensions cause the dissent of those who have attacked the metaphysico-theological doctrines held by me, I propose here to meet, by explanations and arguments, the chief objections they have urged: partly with the view of justifying these doctrines, and partly with the view of guarding against the incorrect interpretations which it appears are apt to be made.

It may be thought that the pages of a periodical intended for general reading are scarcely fit for the treatment of these highly-abstract questions. There is now, however, so considerable a class interested in them, and they are everywhere felt to be so deeply involved with the great changes of opinion in progress, that I have ventured to hope for readers outside the circle of those who occupy themselves with philosophy.

Of course the criticisms to be noticed I have selected, either because of their intrinsic force, or because they come from men whose positions or reputations give them weight. To meet more than a few of my opponents is out of the question.

Let me begin with a criticism contained in the sermon preached by the Rev. Principal Caird before the British Association on the occasion of its meeting in Edinburgh, in August, 1871. Expressed with a courtesy which, happily, is now less rare than of yore in theological controversy, Dr. Caird's objection might, I think, be admitted without involving essential change in the conclusion demurred to; while it might be shown to tell with greater force against the conclusions of thinkers classed as orthodox, Sir W. Hamilton, and Dean Mansel, than against my own. Describing this as set forth by me, Dr. Caird says:

"His thesis is, that the provinces of science and religion are distinguished from each other as the known from the unknown and unknowable. This thesis is maintained mainly on a critical examination of the nature of human intelligence, in which the writer adopts and carries to its extreme logical results the doctrine of the relativity of human knowledge which, propounded by Kant, has been reproduced with special application to theology by a famous school of

philosophers in this country. From the very nature of human intelligence, it is attempted to be shown that it can only know what is finite and relative, and that therefore the absolute and infinite the human mind is, by an inherent and insuperable disability, debarred from knowing. . . . May it not be asked, for one thing, whether, in the assertion, as the result of an examination of the human intellect, that it is incapable of knowing what lies beyond the finite, there is not involved an obvious self-contradiction? The examination of the mind can be conducted only by the mind, and if the instrument be, as is alleged, limited and defective, the result of the inquiry must partake of that defectiveness. Again, does not the knowledge of a limit imply already the power to transcend it? In affirming that human science is incapable of crossing the bounds of the finite world, is it not a necessary presupposition that you who so affirm have crossed these bounds?"

That this objection is one I am not disinclined to recognize, will be inferred when I state that it is one I have myself raised. While preparing the second edition of the "Principles of Psychology," I found, among my memoranda, a note which still bore the wafers by which it had been attached to the original manuscript (unless, indeed, it had been transferred from the MS. of "First Principles," which its allusions seems to imply). It was this:

"I may here remark, in passing, that the several reasonings, including the one above quoted, by which Sir William Hamilton would demonstrate the pure relativity of our knowledge—reasonings which clearly establish many important truths, and with which in the main I agree—are yet capable of being turned against himself, when he definitively concludes that it is impossible for us to know the absolute. For, to positively assert that the absolute cannot be known is, in a certain sense, to assert a *knowledge* of it—is to *know* it as *unknowable*. To affirm that human intelligence is confined to the conditioned is to put an *absolute limit* to human intelligence, and implies *absolute knowledge*. It seems to me that the 'learned ignorance' with which philosophy ends must be carried a step further; and, instead of positively saying that the absolute is unknowable, we must say that we cannot tell whether it is knowable or not."

Why I omitted this note I cannot now remember. Possibly it was because reconsideration disclosed the reply that might be made to the contained objection. For, while it is true that the intellect cannot prove its own competence, since it must postulate its competence in the course of the proof, and so beg the question, yet it does not therefore follow that it cannot prove its own incompetence, in respect of questions of certain kinds. Its inability in respect of such questions has two conceivable causes. It may be that the deliverances of Reason in general are invalid, in which case the incompetence of Reason to solve questions of a certain class is implied by its general incompetence; or it may be that the deliverances of Reason, valid within a certain range, themselves end in the conclusion that Reason is incapable beyond that range. So that, while there can be no proof of competence, because competence is postulated in each step of the demonstration, there may be proof of incompetence either (1) if the

successive deliverances forming the steps of the demonstration, by severally evolving contradictions, show their untrustworthiness, or, (2) if, being trustworthy, they lead to the result that, on certain questions, Reason cannot give any deliverance.

Reason leads both inductively and deductively to the conclusion that the sphere of Reason is limited. Inductively, this conclusion expresses the result of countless futile attempts to transcend this sphere—attempts to understand matter, motion, space, time, force, in their ultimate natures—attempts which, bringing us always to alternative impossibilities of thought, warrant the inference that such attempts will continue to fail, as they have hitherto failed. Deductively, this conclusion expresses the result of mental analysis, which shows us that the product of thought is in all cases a relation, identified as such or such; that the process of thought is the identification and classing of relations; that therefore Being in itself, out of relation, is unthinkable by us, as not admitting of being brought within the form of our thought. That is to say, deduction explains that failure of Reason established as an induction from many experiments. And to call in question the ability of Reason to give this verdict against itself, in respect of these transcendent problems, is to call in question its ability to draw valid conclusions from premises; which is to assert a general incompetence necessarily inclusive of the special incompetence.

Closely connected with the foregoing is a criticism from Dr. Mansel, on which I may here make some comments. In a note to his "Philosophy of the Conditioned" (page 39), he says:

"Mr. Herbert Spencer, in his work on 'First Principles,' endeavors to press Sir W. Hamilton into the service of Pantheism and Positivism together" (a somewhat strange assertion, by-the-way, considering that I reject them both), "by adopting the negative portion only of his philosophy—in which, in common with many other writers, he declares the absolute to be inconceivable by the mere intellect—and rejecting the positive portions, in which he most emphatically maintains that the belief in a personal God is imperatively demanded by the facts of our moral and emotional consciousness. . . . Sir W. Hamilton's fundamental principle is, that consciousness must be accepted entire, and that the moral and religious feelings, which are the primary source of our belief in a personal God, are in no way invalidated by the merely negative inferences which have deluded men into the assumption of an impersonal absolute. . . . Mr. Spencer, on the other hand, takes these negative inferences as the only basis of religion, and abandons Hamilton's great principle of the distinction between knowledge and belief."

Putting these statements in the order most convenient for discussion, I will deal first with the last of them. Instead of saying what he does, Dr. Mansel should have said that I decline to follow Sir W. Hamilton in confounding two distinct, and indeed radically opposed,

meanings of the word *belief*. This word "is habitually applied to dicta of consciousness for which no proof can be assigned: both those which are unprovable because they underlie all proof, and those which are unprovable because of the absence of evidence."[1] In the pages of this review for July, 1865, I exhibited this distinction as follows:

"We commonly say, 'we believe' a thing for which we can assign some preponderating evidence, or concerning which we have received some indefinable impression. We *believe* that the next House of Commons will not abolish Church-rates; or we *believe* that a person on whose face we look is good-natured. That is, when we can give confessedly-inadequate proofs or no proofs at all for the things we think, we call them 'beliefs.' And it is the peculiarity of these beliefs, as contrasted with cognitions, that their connections with antecedent states of consciousness may be easily severed, instead of being difficult to sever. But, unhappily, the word 'belief' is also applied to each of those temporarily or permanently indissoluble connections in consciousness, for the acceptance of which the only warrant is that it cannot be got rid of. Saying that I feel a pain, or hear a sound, or see one line to be longer than another, is saying that there has occurred in me a certain change of state; and it is impossible for me to give a stronger evidence of this fact than that it is present to my mind. . . . 'Belief' having, as above pointed out, become the name of an impression for which we can give only a confessedly-inadequate reason, or no reason at all, it happens that, when pushed hard respecting the warrant for any ultimate dictum of consciousness, we say, in the absence of all assignable reason, that we *believe* it. Thus the two opposite poles of knowledge go under the same name; and by the reverse connotations of this name, as used for the most coherent and least coherent relations of thought, profound misconceptions have been generated."

Now, that the belief which the moral and religious feelings are said to yield of a personal God is not one of the beliefs which are unprovable because they underlie all proof, is obvious. It needs but to remember that, in works on natural theology, the existence of a personal God is *inferred* from these moral and religious feelings, to show that it is not contained in these feelings themselves, or joined with them as an inseparable intuition. It is not a belief like the beliefs which I now have that this is daylight, and that there is open space before me—beliefs which cannot be proved because they are of equal simplicity with, and of no less certainty than, each step in a demonstration. Were it a belief of this most certain kind, argument would be superfluous: all races of men and every individual would have the belief in an inexpugnable form. Hence it is manifest that, confusing the two very different states of consciousness called belief, Sir W. Hamilton ascribes to the second a certainty that belongs only to the first.

Again, neither Sir W. Hamilton nor Dr. Mansel has enabled us to distinguish those "facts of our moral and emotional consciousness" which imperatively demand the belief in a personal God, from those facts of our (or of men's) "moral and emotional consciousness" which,

[1] "Principles of Psychology" (second edition, § 425, note).

in those having them, imperatively demand beliefs that Sir W. Hamilton would regard as untrue. A New-Zealand chief, discovering his wife in an infidelity, killed the man; the wife then killed herself that she might join her lover in the other world; and the chief thereupon killed himself that he might go after them to defeat this intention. These two acts of suicide furnish tolerably strong evidence that these New-Zealanders believed in another world to which they could go at will, and fulfill their desires as they did here. If they were asked the justification for this belief, and if the arguments by which they sought to establish it were not admitted, they might still fall back on emotional consciousness as yielding them an unshakable foundation for it. I do not see why a Feejee-Islander, adopting the Hamiltonian argument, should not justify by it his conviction that, after being buried alive, his life in the other world, forthwith commencing at the age he has reached in this, will similarly supply him with the joys of conquest and the gratifications of cannibalism. That he has a conviction to this effect stronger than the religious convictions current among civilized people is proved by the fact that he goes to be buried alive quite willingly; and, as we may presume that his conviction is not the outcome of a demonstration, it must be the outcome of some state of feeling—some "emotional consciousness." Why, then, should he not assign the "facts" of his "emotional consciousness" as "imperatively demanding" this belief? Manifestly, this principle, that "consciousness must be accepted entire," either obliges us to accept as true the superstitions of all mankind, or else obliges us to say that the consciousness of a certain limited class of cultivated people is alone meant. If things are to be believed simply because the facts of emotional consciousness imperatively demand them, I do not see why the actual existence of a ghost in a house is not inevitably implied by the intense fear of it that is aroused in the child or the servant.

Lastly, and chiefly, I have to deal with Dr. Mansel's statement that "Mr. Spencer, on the other hand, takes these negative inferences as the only basis of religion." This statement is exactly the reverse of the truth, since I have contended, against Hamilton and against him, that the consciousness of that which is manifested to us through phenomena is *positive*, and not *negative* as they allege, and that this positive consciousness supplies an indestructible basis for the religious sentiment ("First Principles," § 26). Instead of giving here passages to show this, I may fitly quote the statement and opinion of a foreign theologian. M. le pasteur Grotz, of the Reformed Church at Nismes, writes thus:

"Is Science, then, the natural enemy of Religion? To preserve our religion, must we cry Science down? Why, Science, experimental Science, is now beginning to speak in favor of Religion; and it is Science that is about to reply at once to M. Vacherot and to M. Comte through the mouth of one of the thinkers of our age, Mr. Herbert Spencer." . . . .

"Here Mr. Spencer discusses the theory of the *unconditioned*, by which word we are to understand God. The Scotch philosopher, Hamilton, and his disciple, Mr. Mansel, say with our French positivists, 'We cannot affirm the positive existence of any thing whatever, except phenomena.' Hamilton and his disciple differ from our countrymen only in this, that they bring in a 'miraculous intervention,' which enables us to believe in the existence of the unconditioned; and in virtue of this truly miraculous intervention the whole system of orthodoxy is set up again. Is it true that we can affirm nothing beyond phenomena? Mr. Spencer holds that in such an assertion there is grave error. The logical side of a question, as he very justly observes, is not the only one: there is also the psychological side; and, as we take it, he proves that the positive existence of the Absolute is a necessary *datum* of consciousness. . . .

"This is the basis of agreement between Religion and Science. In a chapter entitled 'Reconciliation,' Mr. Spencer establishes and develops this agreement on its true ground. . . . Mr. Spencer, by standing on the ground of logic and psychology, without recurring to supernatural intervention, has established the legitimacy, the necessity, and the everlasting permanency of religion itself."

I turn next to what has been said by Dr. Shadworth H. Hodgson, in his essay on "The Future of Metaphysic," published in the *Contemporary Review* for November, 1872. Remarking only, with respect to the agreements he expresses in certain doctrines of mine, that I value them as coming from a thinker of subtlety and independence, I will confine myself here to his disagreements. Dr. Hodgson, before giving his own view, briefly describes and criticises the views of Hegel and Comte, with both of whom he partly agrees and partly disagrees, and then proceeds to criticise the view set forth by me. After a preliminary brief statement of my position, to the wording of which I demur, he goes on to say:

"In his 'First Principles,' (Part I., second edition), there is a chapter headed 'Ultimate Scientific Ideas,' in which he enumerates six such ideas or groups of ideas, and attempts to show that they are entirely incomprehensible. The six are: 1. Space and Time; 2. Matter; 3. Rest and Motion; 4. Force; 5. Consciousness; 6. The Soul, or the Ego. Now, to enter at length into all of these would be an undertaking too large for the present occasion; but I will take the first of the six, and endeavor to show in its case the entire untenability of Mr. Spencer's view; and, since the same argument may be employed against the rest, I shall be content that my case against them should be held to fail if my case should fail in respect to Space and Time."

I am quite content to join issue with Dr. Hodgson on these terms; and will proceed to examine, one by one, the several arguments which he uses to show the invalidity of my conclusions. Following his criticism in the order he has chosen, I begin with the sentence following that which I have just quoted. The first part of it runs thus: "The metaphysical view of Space and Time is, that they are elements in all phenomena, whether the phenomena are presentations or representations."

Whether, by "the metaphysical view," is here meant the view of

Kant, whether it means Dr. Hodgson's own view, or whether the expression has a more general meaning, I have simply to reply that the metaphysical view is incorrect. Dealing with the Kantian version of this doctrine, that Space is a form of intuition, I have pointed out that only with certain classes of phenomena is Space invariably united; that Kant habitually considers phenomena belonging to the visual and tactual groups, with which the consciousness of Space is inseparably joined, and overlooks groups with which it is not inseparably joined. Though, in the adult, perception of sound has certain space-implications, mostly, if not wholly, acquired by individual experience; and though it would seem, from the instructive experiments of Mr. Spalding, that, in creatures born with nervous systems much more organized than our own are at birth, there is some innate perception of the side from which a sound comes; yet it is demonstrable that the space-implications of sound are not originally given with the sensation as its form of intuition. Bearing in mind the Kantian doctrine, that Space is the form of sensuous intuitions not only as *presented* but also as *represented*, let us examine critically our musical ideas. As I have elsewhere suggested to the reader—

"Let him observe what happens when some melody takes possession of his imagination. Its tones and cadences go on repeating themselves apart from any space-consciousness—they are not localized. He may or may not be reminded of the place where he heard them; this association is incidental only. Having observed this, he will see that such space-implications as sounds have are learned in the course of individual experience, and are not given with the sounds themselves. Indeed, if we refer to the Kantian definition of form, we get a simple and conclusive proof of this. Kant says form is 'that which effects that the content of the phenomenon can be arranged under certain relations.' How then can the content of the phenomenon we call sound be arranged? Its parts can be arranged in order of sequence—that is, in Time. But there is no possibility of arranging its parts in order of coexistence—that is, in Space. And it is just the same with odor. Whoever thinks that sound and odor have Space for their form of intuition may convince himself to the contrary by trying to find the right and left sides of a sound, or to imagine an odor turned the other way upward."—(*Principles of Psychology*, § 399.)

As I thus dissent, not I think without good reason, from "the metaphysical view of Space and Time" as "elements in all phenomena," it will naturally be expected that I dissent from the first criticism which Dr. Hodgson proceeds to deduce from it. Dealing first with the arguments I have used to show the incomprehensibility of Space and Time, if we consider them as objective, and stating in other words the conclusion I draw, that, "as Space and Time cannot be either non-entities nor the attributes of entities, we have no choice but to consider them as entities," Dr. Hodgson continues:

"So far good. Secondly, he argues that they cannot be represented in thought as such real existences, because, 'to be conceived at all, a thing must

be conceived as having attributes.' Now, here the metaphysical doctrine enables us to conceive them as real existences, and rebuts the argument for their inconceivability; for the other element, the material element, the feeling or quality occupying Space and Time, stands in the place and performs the function of the required attributes, composing, together with the space and time which is occupied, the empirical phenomena of perception. So far as this argument of Mr. Spencer goes, then, we are entitled to say that his case for the inconceivability of Space and Time as real existences is not made out."

Whether the fault is in me or not I cannot say, but I fail to see that my argument is thus rebutted. On the contrary, it appears to me substantially conceded. What kind of entity is that which can exist only when occupied by something else? Dr. Hodgson's own argument is a tacit assertion that Space *by itself* cannot be conceived as an existence; and this is all that I have alleged.

Dr. Hodgson deals next with the further argument, familiar to all readers, which I have added as showing the insurmountable difficulty in the way of conceiving Space and Time as objective entities: namely, that "all entities which we actually know as such are limited. . . . But of Space and Time we cannot assert either limitation or the absence of limitation." Without quoting at length the reasons Dr. Hodgson gives for distinguishing between Space as *per*ceived and Space as *con*ceived, it will suffice if I quote his own statement of the result to which they bring him: "So that Space and Time, as perceived, are not finite but infinite; as conceived, are not infinite but finite."

Most readers will, I think, be startled by the assertion that conception is less extensive in range than perception; but, without dwelling on this, I will content myself by asking in what case Space is perceived as infinite? Surely Dr. Hodgson does not mean to say that he can perceive the whole surrounding Space at once—that the Space behind is united in perception with the Space in front. Yet this is the necessary implication of his words. Taking his statement less literally, however, and not dwelling on the fact that in perception Space is habitually bounded by objects more or less distant, let us test his assertion under the most favorable conditions. Supposing the eye directed upward toward a clear sky; is not the Space then perceived laterally limited? The visual area, restricted by the visual apertures, cannot include in perception even 180° from side to side, and is still more confined in a direction at right angles to this. Even in the third direction, to which alone Dr. Hodgson evidently refers, it cannot properly be said that it is infinite in perception. Look at a position in the sky a thousand miles off. Now look at a position a million miles off. What is the difference in perception? Nothing. How, then, can an infinite distance be perceived, when these immensely unlike finite distances cannot be perceived as differing from one another, or from an infinite distance? Dr. Hodgson has used the

wrong word. Instead of saying that Space as perceived is infinite, he should have said that, in perception, Space is finite in two dimensions, and becomes *indefinite* in the third when this becomes great.

I come now to the paragraph beginning "Mr. Spencer then turns to the second or subjective hypothesis, that of Kant." This paragraph is somewhat difficult to deal with, for the reason that in it my reasoning is criticised both from the Kantian point of view and from Dr. Hodgson's own point of view. Dissenting from Kant's view, Dr. Hodgson says, "I hold that both Space and Time, and Feeling, or the material element, are equally and alike subjective, equally and alike objective." As I cannot understand this, I am unable to deal with those arguments against me which Dr. Hodgson bases upon it, and must limit myself to that which he urges on behalf of Kant. He says:

"But I think that Mr. Spencer's representation of Kant's view is very incorrect; he seems to be misled by the large term non-ego. Kant held that Space and Time were *in their origin* subjective, but when applied to the non-ego resulted in phenomena, and were the formal element in those phenomena, among which some were phenomena of the internal sense or ego, others of the external sense or non-ego. The non-ego to which the forms of Space and Time did not apply and did not belong was the Ding-an-sich, not the phenomenal non-ego. Hence the objective existence of Space and Time in phenomena, but not in the Ding-an-sich, is a consistent and necessary consequence of Kant's view of their subjective origin."

If I have misunderstood Kant, as thus alleged, then my comment must be that I credited him with an hypothesis less objectionable than that which he held. I supposed his view to be that Space, as a form of intuition belonging to the *ego*, is imposed by it on the *non-ego* (by which I understood the thing in itself) in the act of intuition. But now the Kantian doctrine is said to be that Space, originating in the subject, when applied to the *non-ego* results in phenomena (the *non-ego* meant being, in that case, necessarily the Ding-an-sich, or thing in itself); and that the phenomena so resulting, carrying with them the Space they have been endowed with, become objective existences along with the Space given to them by the *ego*. The subject having imposed Space as a form on the primordial *non-ego*, or thing in itself, and so created phenomena, this Space thereupon becomes an objective existence, independent of both the *ego* and the original thing in itself. To Dr. Hodgson this may seem a more tenable position than that which I ascribed to Kant; but to me it seems only a multiplication of inconceivabilities. I am content to leave it as it stands: not feeling my reasons for rejecting the Kantian hypothesis much weakened.[1]

[1] Instead of describing me as misunderstanding Kant on this point, Dr. Hodgson should have described Kant as having, in successive sentences, so changed the meanings of the words he uses, as to make either interpretation possible. At the outset of his "Critique of Pure Reason," he says: "The effect of an object upon the faculty of repre-

The remaining reply which Dr. Hodgson makes runs thus:

"But Mr. Spencer has a second argument to prove this inconceivability. It is this: 'If Space and Time are forms of thought, they can never be thought of; since it is impossible for any thing to be at once the *form* of thought and the *matter* of thought.' . . . An instance will show the fallacy best. Syllogism is usually held to be a form of thought. Would it be any argument for the inconceivability of syllogisms to say, they cannot be at once the form and the matter of thought? Can we not syllogize about syllogism? Or, more plainly still—no dog can bite himself, for it is impossible to be at once the thing that bites and the thing that is bitten."

Had Dr. Hodgson quoted the whole of the passage from which he takes the above sentence; or had he considered it in conjunction with the Kantian doctrine to which it refers (namely, that Space survives in consciousness when all contents are expelled, which implies that then Space is the thing with which consciousness is occupied, or the *object* of consciousness), he would have seen that his reply has none of the cogency he supposes. If, taking his first illustration, he will ask himself whether it is possible to "syllogize about syllogism," when syllogism has no content whatever, symbolic or other—has non-entity to serve for major, non-entity for minor, and non-entity for conclusion—he will, I think, see that syllogism, considered as surviving terms of every kind, cannot be syllogized about; the "pure form," of reason (supposing it to be syllogism, which it is not), if absolutely discharged of all it contains, cannot be represented in thought, and therefore cannot be reasoned about. Following Dr. Hodgson to his second illustration, I must express my surprise that a metaphysician of his acuteness should have used it. For an illustration to have any value, the relation between the terms of the analogous case must have some parallelism to the relation between the terms of the case with which it is compared. Does Dr. Hodgson really think that the relation between a dog and the part of himself which he bites is like the relation between *matter* and *form?* Suppose the dog bites his tail. Now, the dog, as biting, stands, according to Dr. Hodgson, for the form as the containing mental faculty; and the tail as bitten

sentation, so far as we are affected by the said object, is sensation. That sort of intuition which relates to an object by means of sensation, is called an empirical intuition. The undetermined object of an empirical intuition, is called *phenomenon*. That which in the phenomenon corresponds to the sensation, I term its *matter*' (here, remembering the definition just given of phenomenon, objective existence is manifestly referred to), 'but that which effects that the content of the phenomenon can be arranged under certain relations, I call its *form*' (so that *form* as here applied, refers to objective existence). 'But that in which our sensations are merely arranged, and by which they are susceptible of assuming a certain form, cannot be itself sensation.' (In which sentence the word *form* obviously refers to subjective existence.) At the outset, the 'phenomenon' and the 'sensation' are distinguished as objective and subjective respectively; and then, in the closing sentences, the *form* is spoken of in connection first with the one and then with the other, as though they were the same."

stands for this mental faculty as contained. Now, suppose the dog loses his tail. Can the faculty as containing and the faculty as contained be separated in the same way? Does the mental form when deprived of all content, even itself (granting that it can be its own content), continue to exist in the same way that a dog continues to exist when he has lost his tail? Even had this illustration been applicable, I should have scarcely expected Dr. Hodgson to remain satisfied with it. I should have thought he would prefer to meet my argument directly, rather than indirectly. Why has he not shown the invalidity of the reasoning used in the "Principles of Psychology" (§ 399, second edition)? Having there quoted the statement of Kant, that "Space and Time are not merely forms of sensuous intuition, but *intuitions* themselves," I have written:

"If we inquire more closely, this irreconcilability becomes still clearer." Kant says: 'That which in the phenomenon corresponds to the sensation, I term its *matter;* but that which effects that the content of the phenomenon can be arranged under certain relations, I call its *form*.' Carrying with us this definition of form, as 'that which effects that the content . . . . can be arranged under certain relations,' let us return to the case in which the intuition of Space is the intuition which occupies consciousness. Can the content of this intuition 'be arranged under certain relations' or not? It can be so arranged, or rather, it *is* so arranged. Space cannot be thought of save as having parts, near and remote, in this direction or the other. Hence, if that is the form of a thing 'which effects that the content . . . . can be arranged under certain relations,' it follows that when the content of consciousness is the intuition of Space, which has parts 'that can be arranged under certain relations,' there must be a form of that intuition. What is it? Kant does not tell us—does not appear to perceive that there must be such a form; and could not have perceived this without abandoning his hypothesis that the space-intuition is primordial."

Now, when Dr. Hodgson has shown me how that "which effects that the content . . . . can be arranged under certain relations" may also be that which effects its own arrangement under the same relations, I shall be ready to surrender my position; but, until then, no analogy drawn from the ability of a dog to bite himself will weigh much with me.

Having, as he considers, disposed of the reasons given by me for concluding that, considered in themselves, "Space and Time are wholly incomprehensible" (he continually uses on my behalf the word "inconceivable," which, by its unfit connotations, gives a wrong aspect to my position), Dr. Hodgson goes on to say:

"Yet Mr. Spencer proceeds to use these inconceivable ideas as the basis of his philosophy. For mark, it is Space and Time as we know them, the actual and phenomenal Space and Time, to which all these inconceivabilities attach. Mr. Spencer's result ought, therefore, logically to be—Skepticism. What is his actual result? Ontology. And how so? Why, instead of rejecting Space and Time as the inconceivable things he has tried to demonstrate them to be, he

substitutes for them an Unknowable, a something which they really are, though we cannot know it, and rejects that, instead of them, from knowledge."

This statement has caused me no little astonishment. That having before him the volume from which he quotes, so competent a reader should have so completely missed the meaning of the passages (§ 26) already referred to, in which I have contended against Hamilton and Mansel, makes me almost despair of being understood by any ordinary reader. In that section, I have, in the first place, contended that the consciousness of an Ultimate Reality, though not capable of being made a thought, properly so called, because not capable of being brought within limits, nevertheless remains as a mode of consciousness that is *positive:* is not rendered *negative* by the negation of limits. I have pointed out that—

"The error (very naturally fallen into by philosophers intent on demonstrating the limits and conditions of consciousness) consists in assuming that consciousness contains *nothing but* limits and conditions; to the entire neglect of that which is limited and conditioned. It is forgotten that there is something which alike forms the raw material of definite thought and remains after the definiteness which thinking gave to it has been destroyed," something which "ever persists in us as the body of a thought to which we can give no shape."

This *positive* element of consciousness it is, which, "at once necessarily indefinite and necessarily indestructible," I regard as the consciousness of the Unknowable Reality. Yet Dr. Hodgson says "Mr. Spencer proceeds to use these inconceivable ideas as the basis of his philosophy:" implying that such basis consists of negations, instead of consisting of that which persists *notwithstanding the negation of limits.* And then, beyond this perversion, or almost inversion, of meaning, he conveys the notion that I take, as the basis of philosophy, the "inconceivable ideas" "or self-contradictory notions" which result when we endeavor to comprehend Space and Time. He speaks of me as proposing to evolve substance out of form, or, rather, out of negations of forms—gives his readers no conception that the *Power* manifested to us is that which I regard as the Unknowable, while what we call Space and Time answer to the unknowable *nexus* of its manifestations. And yet the chapter from which I quote, and still more the chapter which follows it, makes this clear—as clear, at least, as I can make it by carefully-worded statements and restatements.

Philosophical systems, like theological ones, following the law of evolution in general, severally become in course of time more rigid, while becoming more complex and more definite; and they similarly become less alterable—resist all compromise, and have to be replaced by the more plastic systems that descend from them.

It is thus with the pure Empiricists and the pure Transcendentalists. Down to the present time disciples of Locke have continued to hold that all mental phenomena are interpretable as results of accumulated individual experiences; and, by criticism, have been led simply to elaborate their interpretations: ignoring the proofs of inadequacy. On the other hand, disciples of Kant, asserting this inadequacy, and led by perception of it to adopt an antagonist theory, have persisted in defending that theory under a form presenting fatal inconsistencies. And then, when there is offered a mode of reconciliation, the spirit of no-compromise is displayed: each side continuing to claim the whole truth. After it has been pointed out that all the obstacles in the way of the experiential doctrine disappear if the effects of ancestral experiences are joined with the effects of individual experiences, the old form of the doctrine is still adhered to, while Kantists persist in asserting that the *ego* is born with intuitional forms which are wholly independent of any thing in the *non-ego*, after it has been shown that the innateness of these intuitional forms may be so understood as to escape the insurmountable difficulties of the hypothesis as originally expressed.

I am led to say this by reading the remarks concerning my own views, made with an urbanity I hope to imitate, by Prof. Max Müller, in a lecture delivered at the Royal Institution last March.[1] Before dealing with the criticisms contained in this lecture, I must enter a demurrer against that interpretation of my views by which Prof. Max Müller makes it appear that they are more allied to those of Kant than to those of Locke. He says:

"Whether the prehistoric genesis of these congenital dispositions or inherited necessities of thought, as suggested by Mr. Herbert Spencer, be right or wrong, does not signify for the purpose which Kant had in view. In admitting that there is something in our mind which is not the result of our own *a posteriori* experience, Mr. Herbert Spencer is a thorough Kantian, and we shall see that he is a Kantian in other respects too. If it could be proved that nervous modifications, accumulated from generation to generation, could result in nervous structures, that are fixed in proportion as the outer relations to which they answer are fixed, we, as followers of Kant, should only have to put in the place of Kant's intuitions of Space and Time 'the constant space-relations expressed in definite nervous structures congenitally framed to act in definite ways, and incapable of acting in any other way.' If Mr. Herbert Spencer had not misunderstood the exact meaning of what Kant calls the intuitions of Space and Time, he would have perceived that, barring his theory of the prehistoric origin of these intuitions, he was quite at one with Kant."

On this passage let me remark, first, that the word "prehistoric," ordinarily employed only in respect to human history, is misleading when applied to the history of Life in general; and his use of it leaves me in some doubt whether Prof. Max Müller has rightly conceived the hypothesis he refers to.

[1] *See Fraser's Magazine* of May last.

My second comment is, that the description of me as "quite at one with Kant," "*barring*" the "theory of the prehistoric origin of these intuitions," curiously implies that it is a matter of comparative indifference whether the forms of thought are held to be *naturally generated* by intercourse between the organism and its environing relations, during the evolution of the lowest into the highest types, or whether such forms are held to be *supernaturally given* to the human mind, and are independent both of environing relations and of ancestral minds. But now, addressing myself to the essential point, I must meet the statement that I have "misunderstood the exact meaning of what Kant calls the intuitions of Space and Time," by saying that I think Prof. Max Müller has overlooked certain passages which justify my interpretation, and render his interpretation untenable. For Kant says "Space is *nothing else* than the form of all phenomena of the external sense;" further, he says that "Time is *nothing but* the form of our internal intuition;" and, to repeat words I have used elsewhere, "He distinctly shuts out the supposition that there are forms of the *non-ego* to which these forms of the *ego* correspond," by saying that "Space is not a conception which has been derived from outward experiences." Now, so far from being in harmony with, these statements are in direct contradiction to, the view which I hold, and seem to me absolutely irreconcilable with it. How can it be said that, "barring" a difference represented as trivial, I am "quite at one with Kant," when I contend that these subjective forms of intuition are moulded into correspondence with, and therefore derived from, some objective form or *nexus*, and therefore dependent upon it; while the Kantian hypothesis is that these subjective forms are not derived from the object, but exist independently in the *ego*, and are imposed by it on the *non-ego?* It seems to me that not only do Kant's words, as above given, exclude the view which I hold, but also that Kant could not consistently have held any such view. Rightly recognizing, as he did, these forms of intuition as innate, he was, from his stand-point, *obliged* to regard them as imposed on the matter of intuition in the act of perception. In the absence of the hypothesis that intelligence has been evolved, it was not possible for him to regard these subjective forms as having been derived from objective forms.

A disciple of Locke might, I think, say that the Evolution-view of our consciousness of Space and Time is essentially Lockian, with more truth than Prof. Max Müller can represent it as essentially Kantian. The Evolution-view is completely experiential. It differs from the original view of the experientialists by containing a great extension of it. With the relatively-small effects of individual experiences, it joins the relatively-vast effects of the experiences of antecedent individuals. But the view of Kant is avowedly and absolutely unexperiential. Surely this makes the predominance of kinship manifest.

In Prof. Max Müller's replies to my criticisms on Kant I cannot

see greater validity than in this affiliation to which I have demurred. One of his arguments is that which Dr. Hodgson has used, and which I have already answered; and I think that the others, when compared with the passages of the "Principles of Psychology" which they concern, will not be found adequate. I refer to them here chiefly for the purpose of pointing out that, when he speaks of me as bringing "three arguments against Kant's view," he understates the number. Let me close what I have to say on this disputed question, by quoting the summary of reasons I have given for rejecting the Kantian hypothesis:

"Kant tells us that Space is the form of all external intuition, which is not true. He tells us that the consciousness of Space continues when the consciousness of all things contained in it is suppressed; which is also not true. From these alleged facts he *infers* that Space is an *a priori* form of intuition. I say *infers*, because this conclusion is not presented in necessary union with the premises, in the same way that the consciousness of duality is necessarily presented along with the consciousness of inequality; but it is a conclusion voluntarily drawn for the purpose of explaining the alleged facts. And then, that we may accept this conclusion, which is not necessarily presented along with these alleged facts which are not true, we are obliged to affirm several propositions which cannot be rendered into thought. When Space is itself contemplated, we have to conceive it as at once the form of intuition and the matter of intuition, which is impossible. We have to unite that which we are conscious of as Space with that which we are conscious of as the *ego*, and contemplate the one as a property of the other; which is imposeible. We have, at the same time, to disunite that which we are conscious of as Space, from that which we are conscious of as the *non-ego*, and contemplate the one as separate from the other; which is also impossible. Further, this hypothesis, that Space is 'nothing else' than a form of intuition belonging wholly to the *ego*, commits us to one of the two alternatives, that the *non-ego* is formless, and that its form produces absolutely no effect upon the *ego*—both of which alternatives involve us in impossibilities of thought."—*Principles of Psychology*, § 399.—*Advance Sheets from Fortnightly Review.*

QUICKER THAN LIGHTNING.

THE Faithful have a tradition that Mohammed, on one occasion, in starting for heaven, upset a pitcher with his foot: he had ninety thousand interviews with the Most High, and, when he returned, the water was not yet spilled from the pitcher. It may be admitted that this was quick work, and that Mohammed was undoubtedly smart; but, when it comes to "interviewing," the Arabs must yield to the Yankees. In the laboratory of Columbia College, Prof. Rood has had interviews with one of the messengers of the Most High at a rate that leaves the prophet nowhere. Besides, with all respect to the hundred million believers, the Mussulman story is but a piece of Oriental fancy, while the Christian reports not only what he has actually seen, but can also

make others see. Our optics are none of the best, but we have seen the professor run down his ethereal game, and can attest that it was more exciting than a horse-race. Let us consider this "descent of man" into the regions of infinitesimal time.

Of all the curious things that science has revealed, none are so confounding to the ordinary reason as what has been learned respecting the order of Nature in its extremest aspect of minuteness. Objects fade away from the customary range of the senses, and we habitually think, what was long believed to be the fact, that there remains nothing more; or, that we find the edge and final termination of things but little beyond what is familiarly recognized. But we now understand that Nature is fathomless below as well as boundless above, and that, beneath the grasp of unaided sense, there are an inexhaustible wealth of wonders, a fixedness of relations, a definite play of interacting forces, and a sharp exactness in the working of law, which we could never infer from the coarser processes of the world of common experience.

As we are to speak of the briefest known duration of luminous effects, it will be proper first to recall how much is involved in the act of sight. When the man of experiment talks to us about what occurs in the thousandth of a second, he is, of course, dealing with something recognized, or which has affected both his body and his mind in that short space of time, and this is necessarily an illustration of how quickly his composite machinery can work. Then the agency which acts upon him must be taken into account, and also the cause of that agency, for they both belong to the same order of activities. When we look upon a source of illumination, as a candle or a star, we are affected by something that is done at those points. The light originates in the vibration of the molecules of matter. These vibrations are communicated to some medium which can convey the impulses at a demonstrated velocity of nearly 200,000 miles per second. The luminous waves strike the retina of the eye, and they are again translated into the molecular vibrations of nervous matter, and the physical influence is turned into a sensation by the organ of consciousness. The act of seeing thus involves the constitution and action of the visible object, the mode of movement of the force, the operation of the organ of vision, the changes of the nerve-line, and the cerebral act of recognition. There is a dynamic chain connecting thought and the object seen through a nether world of minuteness, but where all is correlated in a common scale of relations; and, whenever we see any thing, this whole train of transformations is implicated in the effect. The molecular tremors of Sirius, the ethereal thrills of space, and the rhythmic swing of the nervous elements, are but parts of a unified system of subsensible dynamics. Bearing in mind, then, what is involved in a single act of vision, let us now trace the course of experiment which has led to the latest results regarding its duration.

Phosphorus, the *light-bearer*, as its name implies, has the property, long supposed to be peculiar to it, of faintly shining in the dark. But, if a diamond is exposed to sunshine, and then withdrawn into darkness, it continues feebly luminous for a considerable time, and is, therefore, said to be *phosphorescent*. Other substances, as sulphuret of calcium, and sulphuret of barium, have also been long noted for this property, and recent researches have shown that, so far from being any thing peculiar, the same property is manifested in a much lower degree by a vast number of substances. The differences are in the time the phosphorescence continued after withdrawal from the sun's rays. It was found, in most instances, extremely short, only the small fraction of a second, and it became necessary to devise some means of measuring the time in different cases. A contrivance was necessary which should expose an object to the sun, and then jerk it quickly into total darkness, where it could be seen by the observer if it dragged any light along with it, for even the thousandth of a second.

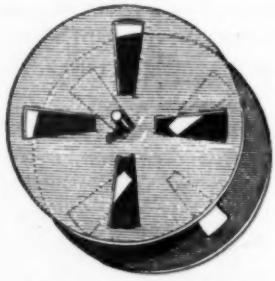
FIG 1.

BECQUEREL'S PHOSPHOROSCOPE.

A contrivance for this purpose was made by Edmund Becquerel, and called the *phosphoroscope*. It consisted of a train of wheels and pinions (Fig. 1) for producing rapid revolving motion. There was a

hollow barrel or case at the top of the machine, pierced with an opening, within which, as seen in the figure, the object to be experimented with is attached to a fixed stand. On the opposite side of the case there is another opening in a corresponding position, not shown in the figure. The outer case does not revolve, but within it there is a pair of disks (Fig. 2) rigidly connected upon a spindle which is turned by the machinery. Each of these disks has four openings, those of the one being not opposite, but midway between those of the other. Of course, then, when these disks are inside the case, it is impossible to see through. The arrangement is then set up in the window of a darkened room, so that one side is turned toward the sun, and the

FIG. 2.



DISKS OF PHOSPHOROSCOPE.

other toward the observer; and, when the disks are turned, the object is alternately exposed to the light from one side, and to the eye from the other; that is, it is seen in a moment after exposure to light, and the duration of the moment can be determined by the rapidity of the rotation. The object, therefore, if not phosphorescent, will never be seen by the observer, as it is always in darkness, except when it is hidden by the intervening disk. But, if its phosphorescence lasts as long as an eighth part of the time of one rotation, it will become visible in the darkness. Suppose, now, that the disks are made to revolve a hundred times in a second, and that the body observed is visible, it is then proved that its phosphorescence lasts the one eight-hundredth of a second, that being the time which elapses between its exposure to the sun and its exposure to the eye. When examined in this way, a very large number of bodies show traces of phosphorescence, although in some cases it is found to last no longer than the ten-thousandth part of a second.

The question was thus opened whether phosphorescence is not a general property of matter, and, to determine this, with the conditions of its manifestation, a more thorough investigation of the subject was needed. Prof. Rood proposed to undertake it, using, if possible, an instantaneous source of illumination—the electric spark. But, in en-

tering upon the inquiry, he soon found himself involved in preliminary difficulties with the spark itself. His phosphorescent investigations remain yet to be carried out, but the results obtained relative to the electric flash are of extreme interest. The full account of the research is given in a series of papers published in *Silliman's Journal*, and, if the reader finds the following statement insufficient in its details, he will know where to go for further explanations.

Since the time of Franklin, the lightning-flash has been regarded as a gigantic electric spark produced in the atmosphere; the inquiry, therefore, involved the nature of the meteorological discharge, as well as of the spark artificially produced. Various attempts to determine the duration of lightning have been made, with varying results. Faraday observed it, without any instruments for measuring the time, which *seemed* to last for a second, but he was doubtful if part of the effect was not due to the lingering phosphorescence of the cloud. Decharme observed the lightning-flashes from a distant storm, which also appeared to last for from a half to an entire second. Prof. Dove employed a revolving disk with colored sectors, and satisfied himself that single flashes of lightning often consisted of a number of instantaneous discharges. It is well known that, when a rapidly-moving train of cars is illuminated at night by lightning, it seems to stand still, that is, the duration of the flash is so brief that no motion of the train is perceptible while it lasts. The wheels are sharply defined as if perfectly motionless, but if they had a blurred aspect we should know that the illumination lasted sufficiently long to render the motion perceptible. Prof. Rood extemporized a simple contrivance for observing lightning, which acted upon this principle. It consisted of a white card-board disk, five inches in diameter, with a steel shawl-pin for an axis, on which it was made to revolve by striking the edge. He traced black figures near the circumference of the disk, and when it was in rapid motion these figures were sometimes seen as sharply as though they had been stationary, although they were often blurred as though the disk had moved through a few degrees during the act of discharge. He then cut narrow, radial apertures into the circumference of the disk, and observed the lightning through these openings. Here, again, the apertures were sometimes seen quite unchanged, but they were more frequently elongated into well-defined streaks some degrees in length. He afterward measured the average rate of rotation imparted to the disk in this way, and arrived at the conclusion that the lightning-flashes on the occasion referred to had a duration of about one five-hundredth of a second. Dissatisfied with the roughness of these observations, Prof. Rood arranged a small train of toothed wheels driven by a spring, which rotated a circular pasteboard disk with four open sectors. This instrument gave more regular and precise results; and, while it was shown that the flash sometimes lasts for a whole second, the suggestion of Dove was clearly verified that each flash "consisted of a consider-

able number of isolated and apparently instantaneous electrical discharges, the interval between the components being so small that, to the naked eye, they constituted a continuous act."

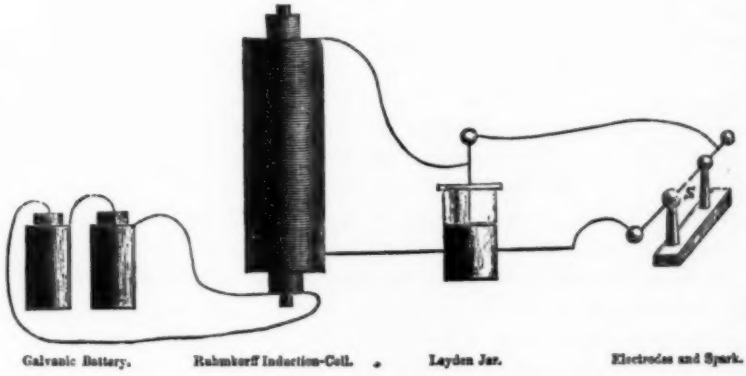
Several curious effects were observed in these experiments. Working with a disk having a single narrow opening, the multiple elements of the discharge were detected with great regularity, and Prof. Rood several times, instead of seeing the opening single, noticed that it had a form resembling the letter X or V, the lines in different positions of the disk having, as it were, got crossed in his eyes by their quick changes of position. On several occasions, when observing with the naked eye, the normal zigzag flashes lasted not less than a second, and the light seemed to pour steadily in a stream from the cloud to the earth. Observations made in the area occupied by a storm, out beyond its edge, and when it was quite distant, gave results that were identical, which the professor thinks furnishes an "argument in support of the hypothesis that zigzag lightning, heat and sheet lightning, etc., are really identical, being, in point of fact, due to the same cause but viewed under different conditions." As the result of these experiments, Prof. Rood concludes: "It is evident, from the foregoing, that the nature of the lightning-discharge is more complicated than has been generally supposed; it is usually, if not always, multiple in character, and the duration of the isolated constituents varies very much, ranging from intervals of time shorter than one one-thousandth of a second up to others at least as great as one-twentieth of a second; and, furthermore, what is singular, a variety of this kind may sometimes be found in the components of a single flash."

Such being the rough conclusions reached concerning the duration of the spark upon a grand scale, let us now consider the results of experiment upon it where all the conditions are in command. In 1835, Mr. Wheatstone attempted to measure the spark of a Leyden jar charged by a common frictional machine. The light from the spark was received upon a mirror mounted upon an axle capable of a high rate of revolution. The image of the spark, being thrown upon the mirror, was reflected to a distant point, and the time of the spark was inferred from the fixity or movement of the image. By using this arrangement, Mr. Wheatstone concluded that the discharge may take place within the millionth of a second; a result which was accepted by the scientific world for a quarter of a century. In 1858, a German named Feddersen, an accomplished physicist, dissatisfied with Wheatstone's results, entered upon a careful reëxamination of the subject. He used the revolving-mirror arrangement with frictional electricity; but, as Wheatstone had driven his machinery by *strings*, Feddersen adopted a train of *toothed wheels*, and with this form of mechanism he found that the image of the spark was drawn out by the revolving mirror into a whitish streak which indicated that the time of the discharge was not less than the twenty-five-thousandth of a second, while

it was inferred that the spark, instead of being a simple effect, is composite like the lightning, and is made up of several elements.

Such were the incomplete and discordant results of the investigation when it was undertaken by Prof. Rood. The arrangement he devised consisted of two parts, one for the production of the spark, and the other for measuring it. Fig. 3 represents the first combination. A galvanic battery was used to generate the electricity; this was connected with a large Ruhmkorff coil, which was again connected with a Leyden jar, and this with the electrodes for producing the spark, *S*,

FIG. 3.

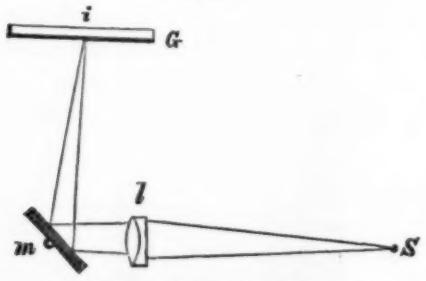


which were adjustable for varying its "striking distance." Connected with the wires between the battery and the coil was an automatic "interruptor" for breaking the circuit from three to six times in a second, by which the frequency of the discharges could be regulated. Leyden jars of different sizes could be used so as to give sparks of all degrees of strength and intensity.

In the second part of his arrangement, Prof. Rood, like his predecessors, employed a revolving mirror, turned by the gearing of Becquerel's phosphoroscope (Fig. 1), with the addition of an extra wheel and a weight to drive it. With this he could get 350 revolutions of the mirror per second, with a smooth and uniform motion. In order to measure exactly the rate of rotation, the cylinder on the lowest wheel was made to wind up a fillet of paper, upon which dots were made by an electro-magnetic apparatus, regulated by a seconds-pendulum, when a simple calculation gave the rate of the wheel to which the mirror was attached, and the regularity of the train was thus put to a sharp test. The light of the spark *S* (Fig. 4), passing through an achromatic lens, *l*, struck the mirror, *m*, and was reflected upward, forming an image at *i*, on the plate of ground glass *G*. The image of the spark on the ground glass was viewed from above, and its position and form were carefully measured by several methods. Of course, if the

spark was *absolutely instantaneous*, its image thrown upon the ground glass would be exactly the same, whether the mirror was motionless or was revolving at the highest speed. But, if the spark had an appreciable duration, its image would be prolonged or drawn out into a streak, the length of which must depend upon the time of discharge. The rate of the mirror's rotation being known, also the distance, *m i*, and the length of the streak, it was easy to calculate the total duration of the spark.

FIG. 4.



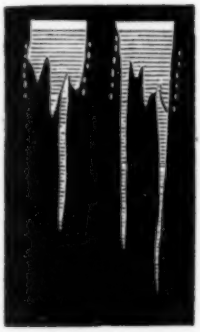
REVOLVING-MIRROR ARRANGEMENT.

Prof. Rood now had the subtile agent he was pursuing pretty effectually in his grasp, and the results that came out were very striking. The ordinary spark was found to be a highly-complex effect; to consist of diverse and successive elements, and, in fact, to have its periods and orderly history just like the geology of the globe. But, while the "vast durations" of Lyell and Dana are vague and inferential, these infinitesimal periods could be demonstrated with the greatest exactness. The previous discordant results were reconciled, Feddersen being justified in assigning a longer period for the total duration of the spark, and Wheatstone's time holding true of its elements.

With a Leyden jar of about a quart capacity (114.4 square inches of coating), and all the connections as short as possible, so as to offer the least amount of resistance to the electric flow, with brass balls as electrodes, with a striking distance of about the twenty-fifth of an inch, and the velocity of the mirror up to 223 per second, the image of the spark thrown upon the ground glass and viewed by the naked eye was drawn out into a streak one and a half or two inches long, the length, however, varying with the speed of the mirror. The aspects of the image are represented in Fig. 5. The first part was pure white, which shaded into a brownish-yellow tint, passing on into a pretty distinct green. When a polished plate of glass was substituted for the ground glass, and a small magnifier was used to observe the image, a series of bright points, on each side of the streak, became visible, in the positions indicated by the dots in Fig. 5. With high velocities, this succession of points was beautifully developed, and it consists of a series of separate discharges following the first. It was thus found that the

Leyden jar furnished a number of single sparks, each time the coil was excited, the number varying between one and thirty, according to circumstances. The whole proceeding consumed an interval of time often as great as one-fiftieth of a second; that is, the jar loaded up and discharged itself twenty or thirty times in that period. Prof. Rood found the number of elements of the spark to vary with its length, the nature of the electrodes, and the size of the jar. Short sparks are more complex than long ones, small jars give more than large ones, and metallic points a greater number than balls. The point to be determined was, the duration of the several elements of the spark, and especially of its quickest element. In one case of a discharge lasting the fiftieth of a second, it began with an ordinary spark, followed by a pale-violet light, lasting about one-sixtieth of a second, and then came a compact

FIG. 5.



IMAGES OF SPARK DRAWN OUT.

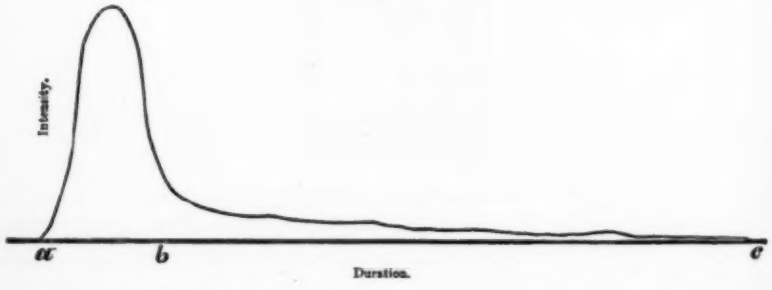
body of ten or twenty sparks, this last act continuing for about one two-hundredth of a second. The results of the inquiry are thus stated by Prof. Rood: "From the foregoing, then, it appears that, if a jar, having a metallic coating of about one hundred square inches, be connected, as above described, with an induction-coil, its discharge will be effected by a considerable number of acts, of which the first is by far the most intense. Further, the metallic particles, heated up by the first discharge to a white heat, almost instantly assume a lower temperature, marked by a corresponding change from white to brownish yellow; and, as their temperature continues to fall, the tint changes, in the case of brass electrodes, to green; in that of platinum, to a gray or violet-gray. These observations further demonstrated the fact that four ten-millionths of a second is an interval of time quite sufficient for the production of distinct vision."

It was also shown that the first act of the electric explosion, represented by the white band, lasted through an interval of time so short as to be immeasurable. It was proved that it could not occupy more

than the millionth or the half a millionth of a second, but how much less time it might occupy remained to be determined.

Prof. Rood now prepared for a more rigorous course of experiments. He used a small Leyden jar, with a surface of eleven inches, about equal to a moderate-sized wine-glass. To secure greater exactness of observation, he devised a peculiar micrometer, consisting of five lines ruled on a plate of glass smoked by lamp-black. This plate was placed between *l* and *S* (*see* Fig. 4), but quite near to the latter, and an image of the lines reflected from the mirror was formed on the clear glass at *i*. The lines were observed by a microscope magnifying ten diameters. In using this micrometer, the measurement was effected by noticing at what rate of the revolving mirror the lines in the image at *i* were *obliterated*, this obliteration being due to the circumstance that by the motion of the mirror the dark lines were superposed on the bright lines. The individual spark now produced was about a millionth of a second in duration, but the faint train was still observable. There was still the brilliant body of the spark appearing, first followed by a faint streak of less than one-hundredth the illuminating power of the first stage. The diagram, Fig. 6, represents the intensity

FIG. 6.



and time of the spark. The elevation, or peak, *a b*, shows the intensity of the first compact body of the spark, and the line *a c* the duration of the whole effect. The point was to get the time of *a b*, which Prof. Rood had proved must be regarded as a distinct act in the succession of effects. All precautions for observation being carefully made, the driving-weight was gradually increased, and the speed of the mirror carried up to 350 revolutions per second, when the lines of the image, which at first remained visibly as distinct as with a stationary mirror, became regularly less distinct, and at length vanished by the gradual superposition of the white and black lines. Prof. Rood says: "It was proved successively that the duration was less than eighty, sixty-eight, fifty-nine, fifty-five billionths of a second; and, finally, the lines, after growing fainter and fainter, entirely disappeared, giving as the result a duration of forty-eight billionths of a second." By reducing the striking distance, a still lower figure was

reached, so that the professor states that "the duration of the first act of the electrical discharge is in certain cases only forty billionths of a second, an interval of time just sufficient to enable a ray of light to travel over forty feet." The duration was twenty-five times smaller than had ever before been measured. In this infinitesimal portion of time a strong and distinct impression upon the retina is made, so that "the letters on a printed page are plainly to be seen; also, if a polariscope be used, the cross and rings around the axis of crystals can be observed with all their peculiarities." Nor is this all; "as the obliteration of the micrometric lines could only take place from the circumstance that the retina retains and combines a whole series of impressions whose joint duration is forty billionths of a second, it follows that a much smaller interval of time will suffice for vision. If we limit the number of views of the lines presented to the eye in a single case to ten, it would result that four billionths of a second is sufficient for human vision."

We saw at the outset how much an act of vision involves, and we have now some idea of how long it takes. If the discharge of the thunder-cloud occupies, as was stated, the one five-hundredth of a second, the "interviews" of our philosopher with the "amber-spirit" were at least fifty thousand times "quicker than lightning."

THE EMOTIONAL LANGUAGE OF THE FUTURE.

MR. SPENCER recently called the attention, in a very interesting passage of his "Psychology," to those secondary signs of a feeling which are to be found in abortive attempts to conceal it. "A state of *mauvaise honte*," he well says, "otherwise tolerably well concealed, is indicated by an obvious difficulty in finding fit positions for the hands." A great mental agitation, though prevented from breaking out into violent expression, is pretty certain to betray itself in the awkward, shuffling movements which are made to curb and suppress it. Such indirect signs of emotion Mr. Spencer calls its secondary natural language.

The fact that many of our emotions now betray themselves only through the incompleteness of the effort of will to disguise them is not a little curious, and offers several lines of interesting inquiry. It at once suggests how very little play for emotional expression the conditions of modern society appear to allow. For it seems tolerably certain that the voluntary hiding of feeling is a late attainment in human development, and is forced on us simply by the needs of advancing civilization. Savages, for the most part, know little of concealing their passions, and this makes them so good a psychological

study. Children, too, who may be supposed to represent the earlier acquirements of the race, are proverbially unfettered in the expression of their sentiments. In like manner, in the various ranks of our civilized society, we see that, while a cultivated lady appears to all distant onlookers to have a mind dispassionate and undisturbed by agitating feelings, a west-country maid reveals her curiosity and wonder, her alternations of joy and misery, with scarcely a trace of compunction. If we go low enough down the social scale we find the freest utterance of feelings, and it is only when, in retracing our steps, we arrive at a certain stage of culture that we discover signs of an active emotional restraint. Where this self-control is defective we have Mr. Spencer's secondary emotional signs. Higher up, among a few specially cultivated persons, the acquisition of this power of concealment appears to be complete, and we have a type of mind capable of a prolonged external serenity unruffled by a gust of passionate impulse. The survey of these facts at once prompts the question whether the expression of our feelings by smile, vocal changes, and so on, is destined to disappear with a further advance of social organization. To attempt to answer such a question directly and briefly would perhaps betray too much confidence. We may, however, seek to define the various paths of inquiry to be pursued before a final answer can be arrived at, and to hint at the probabilities of the problem under its various aspects.

First of all, then, with respect to the distinctly unsocial feelings, the answer seems to be tolerably clear. It being generally allowed by biologists that the looks and gestures accompanying anger, jealousy, and pride, are simply survivals of hostile actions, the nascent renewal of an attitude preliminary to attack, it is natural that they should appear only in transitions of society from a barbaric to a civilized condition. When the age of destructive conflict, individual and racial, shall have become the curious research of antiquaries, it may be presumed that any bodily movements known to have grown out of these struggles will cease from sheer desuetude. Indeed, one may perhaps, without too optimist a bias, refer to the fact that all the stronger manifestations of anger and malice have already become unfamiliar in real life, so that when we see their imitations on the stage they are apt to appear ridiculously forced. The better part of modern society has put such a ban on the ugly signs of rage that our only means of discovering traces of this passion in a man is some incompletely suppressed emotional movement, or some too violent effort to command the muscles of expression. After many more generations shall have practised the difficult art of noiselessly crushing out with the foot an incipient wrath, it will be hard if such offenses to the eye as frowning brow and scornful mouth do not entirely disappear.

But the progress of social refinement probably affects other expressions than those of the distinctly hostile sentiments. It tends to

confine within ever narrower limits all manifestations of unpleasant feeling. Since it is a grateful thing to witness pleasurable feeling, and painful to see the expression of suffering in another, a polite form of society does all it can to encourage the one and to suppress the other. A man is for the most part supposed to be able to obtain all needed sympathy, in his troubles, from his family and his intimate friends. Before the rest of the world he is expected to hide his grief and maintain a cheerful aspect. It is one of the delicate forms of sensibility, produced by a high culture, to be fearful of obtruding one's feelings on unconcerned onlookers. This growing perception of the vulgar aspects of uncontrolled emotional display appears to have much to do with the partial concealments of feeling of which Mr. Spencer speaks. But comparatively few persons are completely able to hide a sharp and sudden vexation, however public the occasion of experiencing it. An annoying piece of intelligence, affecting, it may be, one's matrimonial chances or equally dear ambitions, will very likely call up a momentary expression of dismay even in presence of a fashionable company. We wonder to how many persons it is still a necessity, under the smart of a sudden disappointment, to flee as soon as possible from all spectators, and relieve the pressure of emotion by a few energetic expletives, if not a spare shower of tears? We do not know how many ages it may require to discipline our species in a perfect concealment of painful feeling; but, at present, it looks as though we were passing through the hardest stages of this schooling.

One other influence which probably contributes to make emotion more and more private and invisible is the partial revival of the Stoical doctrine that all sentiment is a moral weakness. This idea appears to hold most sway in our own country, and especially among those classes who are most concerned to maintain a not too obvious gentility. A common supposition among young aspirants to social rank seems to be, that lofty breeding is best seen in a uniformly passionless and vacuous arrangement of the facial muscles. To appear interested in any object in his environment strikes the pseudo-aristocrat as a pitiable infirmity of vulgar minds. The ways in which this curious self-imposed check acts are at times very funny. We remember hearing Macready give a series of readings to a fashionably-dressed assembly, in a small provincial town, and we were much struck by the almost heroic efforts which many of the company made to conceal the emotion so powerfully aroused by the tragedian's art. Possibly English people are less impressible by scenic display and music than Continental nations. Whether this be so or not, it is very curious to contrast the perfectly apathetic aspect of an assembly at Covent Garden with the lively demonstrations of an audience at a Paris opera, or the deep, earnest absorption of the worshipers of Wagner at Berlin or Munich. This notion that it is the final attainment of civilization to appear impartially indifferent to every thing about one, and constantly to pre-

serve the semblance of an equanimity which knows nothing of the agitation of pleasure or pain, may be expected to give the last touch of refinement to emotional expression.

If these were all the facts bearing on the future of our emotional life, we might well inquire what effect the habitual suppression of emotional expression is likely to have on the quality of the emotions themselves. It is probably clear to everybody that our feelings are very much affected by the range of free expression accorded them. At least the violent intensity of a passion is destroyed by successful control of all the muscles, and, even if a slow, smouldering fire of hate or jealousy may coexist with a comparatively quiet exterior, the emotional force is in this case robbed of its glory. It would thus appear that, with social progress, as men are thrown more and more in each other's society, their feelings will undergo a very considerable transformation; some types of emotion disappearing, it may be, altogether, the rest being so mollified as to be scarcely recognizable as the venerable forms of human love, terror, and joy. But, oddly enough, we find another set of influences, due to the very same social conditions as the first, which tends to counteract these, fostering and deepening feeling, and encouraging its manifestations. Mr. Spencer thinks that the habit of expressing pleasure and pain arose as animals became gregarious. This condition exposed the members of the same flock to common experiences of danger, etc.; and in this way, from uttering the sounds of terror under like circumstances and at the same times, they would come to interpret them when given forth by their companions. At the same time the gregarious mode of life clearly made animals able to assist one another in a large variety of ways. Now, on this supposition, which seems extremely plausible, the habit of expressing feeling is an attainment of social life, and, so far from disappearing with the advance of this life, it should, one would think, go on developing. In point of fact, we see in a number of ways how social progress serves to enlarge the area of sympathetic feeling. As a man becomes more of a citizen, he is probably more and more desirous to be in unison of feeling and intention with his fellow-citizens, at least with that section of them whom he most respects. The sympathy he looks for presupposes, it is clear, some expression of his own feelings, and a responsive expression on the part of his neighbors. In this way, then, there are two tendencies of social culture curiously conflicting in their results. By virtue of the one a man seeks to repress feeling and not to obtrude it unnecessarily on his fellow-citizens. By force of the other he is ever craving with more and more vigor for a lively interchange of sentiments with others. What resultant, it may be asked, do these opposite forces produce?

Without trying to determine the precise direction of this compound effect, it may be just suggested that a kind of compromise between the opposing forces is frequently effected by means of lan-

guage. By this medium we may convey most minutely and accurately the fact of a feeling and define its nature, without bringing it forward as a vivid and naked reality. It is highly disagreeable to see a look of disgust in another's face, but we do not quite so strongly object to a man's telling us the cause of such a feeling and leaving us to imagine by inference the nature of the emotion itself. Language, while defining the precise variety of sentiment, contains also, in its ever-varying modulation of voice, its changes of pitch, intensity, and *timbre*, a large apparatus of proper emotional expression. Moreover, it seems fully allowable to accompany speech with a variety of other emotional signs which are looked on as silly and weak if presented independently. We rather expect conversation to be brightened by the many subtile changes of the facial muscles and the refined and subdued gestures peculiar to our nation. If a person habitually wears a half giggle, we are probably struck by the imbecility of this meaningless display. So too when a man meets us in the street looking evidently soured and retaliative, we rather wish he would reserve these unamiable exhibitions for his sympathetic friends. We have, in a word, grown intellectual much faster than we have become emotional, and we cannot suffer feeling to exhibit itself without some explanation of its nature and causes being offered at the same time. If a man will unbosom to us his sorrow or his joy fully and intelligibly, we profess ourselves willing, provided he is not too wearisome and exacting, to lend him a patient ear and to endeavor to enter into his peculiar experiences; but, without this explanatory recital, the evidences of feeling are apt to appear unmeaning, if not actually offensive.

We may just point to another influence which still further complicates this question of emotional expression—namely, the growing demands made by social refinement on the expression of kindly interest in other people's concerns. While a man is judged to be inconsiderate if he is frequently intruding his personal feelings in social intercourse, rigid politeness requires us for the most part to lend an appreciative ear to the tale of woe, however dull it may happen to prove. This law calls into existence a very curious group of half-artificial expressions. The degree to which polite persons have nowadays to assume feeling may well alarm any one who cares much for the honesty of social intercourse. We all know probably the drawing-room smile of some of our lady friends. It is something quite unique, never appearing in other places and at other times, but presenting itself at the right moment with all the certainty of an astronomical phenomenon. So too we know persons whose voices undergo a most curious change when called on to converse with a stranger, especially one of the opposite sex. No doubt some slight part of the display may be set down to an unavoidable excitement, but the main features of it would seem to be deliberately assumed. In this way it

appears that, owing to the requirements of modern society, our volitions are called upon now to check feeling, now to force it into play. The studied graces of smile, dilating eye, and mellifluous voice, make up a perfectly new order of *quasi* expressions, which might perhaps in a highly-artificial state of society gradually supplant many of the older and familiar forms of emotional utterance. Whether the agencies which tend to sustain genuine emotional expression will prove to have more vitality than those which go to suppress it, and how far, supposing spontaneous utterances of emotion to grow out of date, artificial imitations of them will continue in fashion, are points which we do not attempt to determine. Enough has been said, perhaps, to show how curiously complex are the conditions of the problem.—*Saturday Review.*

GENESIS, GEOLOGY, AND EVOLUTION.[1]

By Rev. GEORGE HENSLOW F. L. S., F. G. S.

THE theory, or rather doctrine, of the Evolution of Living Things has not yet received that uniform acceptance to which it is undoubtedly entitled. That it will in time become generally received may be reasonably presumed; but at present, with many theologians at least, the creative hypothesis obstinately holds its ground. Two causes may be assigned to account for this fact. First, there is the preconceived but erroneous idea of the method of creation derived from a misconception of the first chapter of Genesis. Secondly, there is the unfortunate but very general want of any scientific training, not only among the clergy, but in the public generally; and, as a result, there is that absence of a due power of appreciation of the arguments of the scientific man, which is so conspicuous in their style of reasoning

In order, therefore, that the proof of the wisdom and beneficence of the Almighty, as shown in the processes of evolution, may not be considered as based on unsound premises, it will be desirable to point out the untenableness of the present theological position, as well as the grounds upon which evolution is founded; and which will, let us hope, be soon recognized as incontrovertible by all who seek the truth in earnest. Until comparatively recent times the book of Genesis was supposed to reveal in its first chapter an explicit account of the origin of living things, namely, by direct creative fiats of the Almighty. All the known animals and plants being far fewer than at the present day, their differences were more pronounced than their resemblances. Each animal and plant was observed to bring forth

[1] From his recently-published work, "Evolution and Religion."

its offspring "after his kind," generation after generation, without any noticeable change. Any other animals than those now living on the globe were never conceived. Fossil shells were supposed to be either deep-sea creatures thrown up upon the beach, or, if found on land and upon hills, easily accounted for by the Deluge.

Every living thing was believed to have been created at once by the word of the Lord: and all within the space of six literal days.

When geology came to be studied with some philosophic spirit, it was soon discovered that many fossils were not of living species; that six days was incontestably too short a period to account for geological phenomena; that a flood, even if conceded to have been universal, was unable to solve many a problem of disturbance and stratification. Moreover, it was perceived that the earth's structure was separable into several strata; and that each stratum contained a group of fossils unknown either in the stratum above or below it; and upon this discovery was based the principle that disconnected strata might be recognized by the identity of their organic remains. In addition to these facts, the phenomena now known as *dislocation*, *contortion*, *upheaval*, *unconformability*, and others, frequently occurred, and apparently often during periods intervening between the deposition of strata.

These latter appearances, taken into consideration with the daily phenomena of volcanic action, induced the geologist to conceive, and the theologian to adopt, the theory of successive creations after cataclysmic and predetermined destructions of all existing life by the Almighty: while, to meet the now well-established truth of almost infinite ages having elapsed, the theologian adopted the interpretation of *ages* for the Hebrew word *yōm* or *day*. If, however, the first chapter of Genesis be read without any reference to or thought of geological discoveries, and the first three verses of the second chapter be carefully compared with the fourth commandment, it will not appear how any notion of an indefinite time can be given to the word "day" at all. The writer of Genesis seems to signify a day in the ordinary sense, and apparently without any conception of indefinite periods at all.

Geology ceased not to pursue her avocations steadily and uncompromisingly.

The study of the rocks soon brought to light a large increase of the number of strata: so that at the present day there are *thirteen* "formations," embracing *thirty-nine* principal "strata," the strata themselves being often subdivided into minor ones. If, therefore, the miraculous recreations be true, they must have been very numerous. But with the discovery of additional strata a larger insight was obtained into the distribution in time of animal and vegetal life. It was then discovered that these "created groups" were not so rigidly defined as at first supposed, and consequently the rule established by geologists themselves can only be applied cautiously in attempting to

parallel distant strata—though some species appear to characterize strata respectively, yet many range up and down through other than those in which they attain their maximum development, or of which they may be especially characteristic.

Two difficulties thus arose: the increase of miraculous interferences *seemed to increase proportionately their improbability;* especially as there was no corroboration this time from the Word of God; while the fact of species ranging through several *strata* threw another stumbling-block in the way of the cataclysmic theory; for either they must have been recreated two or three times, or else lived through the supposed cataclysms considered as designed methods of destruction.

Another class of phenomena now appeared, to show a still greater difficulty in the way of belief in the creative hypothesis. Zoology, botany, as well as paleontology, gradually increased the number of living and extinct forms almost indefinitely; and in proportion as fresh discoveries were made, so it was found that numbers of forms took up positions, when classified, *intermediate* to other forms hitherto well distinct—"osculant" or intercalary forms as they are called. These often increased so much, that even genera well marked at first became blended together by transitional or intermediate forms.

Hence it has come to pass, from the result of this discovery, that so far from forms or types of organisms being easy and of a precise character, in accordance with the idea of each being well defined *after his kind*, systematic zoology and botany are the most difficult tasks a naturalist can undertake. Here, then, an overwhelming difficulty, only to be fully appreciated by a really scientific person, rises against the conception of each kind having been specially created as we see them now. Indeed, it may be added that the very idea of *kind* or *species* has been resolved into an abstract conception, finding in Nature generally no more than a relative existence.

Fresh difficulties were still in store, which must be overcome if the former theory of creation is to obtain any longer—horticulture, floriculture, agriculture, and the breeding of animals, have rapidly risen to become important and flourishing occupations. From their pursuit it was soon discovered that kinds reproducing their like *never did so absolutely*, but that offspring appeared always to differ from their parents in some trifling if not considerable degree. This property of Nature, to which also the human race is invariably subject, man has seized upon, and by judicious treatment can almost mould his cattle to whatever form he pleases, or stock his fields and gardens with roots of any form or with flowers of any shade of color required. After many years of successful propagation, generation after generation, we have now arrived at the result that animals and plants can be produced by careful breeding and selection, which, had they been wild, our earlier naturalists would have undoubtedly regarded as having been respec-

tively created at the beginning of the world! Here, then, we have a practical basis of argument to account for the many transitional forms which geology reveals in the past history of the world, as well as among the plants and animals living at the present day.

Yet another fact may be mentioned. Geographical botany and zoology began to be studied as travellers stocked our museums and herbaria with an ever-increasing number of beings brought from all parts of the world; and the (so to say) capricious distribution of identical forms in far-distant places—now explicable on the theory of migration and subsequent isolation—as well as the appearance of representative forms of allied though different kinds in certain districts, explicable *only* on the theory of descent with modification, has a strong *prima-facie* appearance against the theory of individual creations, even if geology did not furnish undoubted evidence of very frequent interchanges between land and sea having taken place. Without at present giving more reasons, the above will be sufficient to show cause why Science has found herself compelled to secede from the cramping toils of the creative hypothesis, and to take up that of the evolution of living things as better explaining *all* the foregoing phenomena. In proportion as the probability of the former was seen to decrease, so in the same degree does that of evolution increase. Hence, at the present day the argument in favor of development of species by natural laws may be stated in the following terms, viz.: "It is infinitely more probable that all living and extinct beings have been developed or evolved by natural laws of generation from preëxisting forms, than that they with all their innumerable races and varieties should owe their existences severally to creative fiats."

But, even now, asks the theologian, Does not this theory controvert the Bible, for we are distinctly told that God created every thing after its kind?

In reply, it may be confidently shown that the theologian cannot be sure of the value of his interpretation of the first chapter of Genesis, at least so far as he attempts to draw scientific deductions from it. Thus it may be observed to him that the words "create" and "make" are used indifferently; that no definition is given to insure accuracy as to their right interpretation. It is not stated whether God created out of nothing or out of eternally or at least preëxisting matter. Moreover, in addition to the statement that God created or made all things, there is the oft-repeated assertion embodied in the word *fiat*, but apparently overlooked, that He enjoined the earth and the waters to bring forth living forms. What does this expression imply?

The use of the imperative mood can only signify *an agent other than the speaker.* If, therefore, it be maintained that the sentence (ver. 21) "God created every living thing that moveth" signifies He made them by his direct Almighty fiat, it may be equally maintained that the sentence "Let the waters bring forth abundantly every mov-

ing creature" implies secondary agents to carry out the will of the Lord. Such might be said to witness to natural law, which, after all, is but a synonym for the will of God.

The real basis of the controversy between dogmatic theology and this deduction of Science is simply this: The former has established a creed based upon erroneous impressions derived from Scripture, and, from having had power in former days to enforce its opinions, they were credulously received without hesitation as long as no one dared to or even could controvert them. It is the reluctance to surrender this power to Science as much as the idea of her offering any opposition to theology that urges at least one body so obstinately to resist her advances. Nearer home the opposition rests more on the latter ground; and it will not be until the representatives of our theology can see and confess their false impressions of the meaning of the first chapter of Genesis, that the doctrine of evolution can be hoped to make any great progress among them.

Let us briefly review their false positions. They first clung to the "six days of creation;" they found they were compelled to surrender the idea, and immediately adopted the interpretation of *yōm* signifying an indefinite period. Again, notice their readiness in adopting the theory of cataclysms and recreations, a second time to the detriment of Genesis, which furnishes no warrant for the idea; for even if six days be presumed to represent six cataclysms, geology furnishes no corresponding evidence. It was a pure fiction altogether. And even now they steadily oppose the doctrine of evolution. But surely as each stronghold of theology has been quietly taken by Science—not so much by offensive attack as by undermining and leaving the edifice to crumble of itself—the tardy and ungracious capitulations hitherto offered only insure the ultimate surrender a matter of patient expectation. *A time will shortly come* when the creative theory must succumb altogether and the doctrine (not the theory) of evolution will be as much recognized as a fundamental truth of science and theology as the revolution of the earth itself.

GROWTH AND DECAY OF MIND.

"And so from hour to hour we ripe and ripe,
And then from hour to hour we rot and rot,
And thereby hangs a tale."—*As You Like It.*

FEW subjects of scientific investigation are more interesting than the inquiry into the various circumstances on which mental power depends. By mental power I do not mean simply mental capacity, or the potential quality of the mind, but the actual power which is the resultant, so to speak, of mental capacity and mental

training. The growth and development of mental power in the individual, and the process by which, after attaining a maximum of power, the mind gradually becomes less active, until in the course of time it undergoes at least a partial decay, form the special subjects of which I propose now to treat; but, in order to form clear ideas on these subjects, it will be necessary to consider several associated matters. In particular, it will be desirable to trace the analogy which exists between bodily and mental power, not only as respects development and decay, but with regard to the physical processes involved in their exercise.

It is now a well-established physiological fact that mental action is a distinctly physical process, depending primarily on a chemical reaction between the blood and the brain, precisely as muscular action depends primarily on a chemical reaction between the blood and the muscular tissues. Without the free circulation of blood in the brain, there can be neither thought nor sensation, neither emotions nor ideas. It necessarily follows that thought, the only form of brain-action which we have here to consider, is a process not merely depending upon, but in its turn affecting, the physical condition of the brain, precisely as muscular exertion of any given kind depends on the quality of the muscles employed and affects the condition of those muscles, not at the moment only, but thereafter, conducing to their growth and development if wisely adjusted to their power, or causing waste and decay if excessive and too long continued. It is important to notice that this is not a mere analogy. The relation between thought and the condition of the brain is a reality. So far as this statement affects our ideas about actually existent mental power, it is of little importance; for it is not more useful to announce that a man with a good brain will possess good mental powers than to say that a muscular man will be capable of considerable exertion. But as it is of extreme importance to know of the relation which exists between muscular exercise and the growth or development of bodily strength, so it is highly important for us to remember that the development of mental power depends largely on the exercise of the mind. There is a "training" for the brain as well as for the body—a real physical training—depending, like bodily training, on rules as to nourishment, method of action, quantity of exercise, etc.

When we thus view the matter, we at once recognize the significance of relations formerly regarded as mere analogies between mental and bodily power. Instead of saying that, as the body fails of its fair growth and development if overtaxed in early youth, *so* the mind suffers by the attempt to force it into precocious activity, we should now say that the mind suffers in this case in the same actual manner—that is, by the physical deterioration of the material in and through which it acts. Again, the old adage, "mens sana in corpore sano," only needs to be changed into "cerebrum sanum in corpore sano," to

express an actual physical reality. The processes by which the brain and the body are nourished, as well as those which produce gradual exhaustion when either is employed for a long time or on arduous work, not only correspond with each other, but are in fact identical in their nature; so that Jeremy Taylor anticipated a comparatively recent scientific discovery when he associated mental and bodily action in the well-known apothegm, "Every meal is a rescue from one death and lays up for another; and while we think a thought we die." This is true, as Wendell Holmes well remarks, "of the brain as of other organs: the brain can only live by dying. We must all be born again, atom by atom, from hour to hour, or perish all at once beyond repair."

And here it is desirable to explain distinctly that the relations between mind and matter which we are considering are not necessarily connected with any views respecting the questions which have been at issue between materialism and its opponents. We are dealing here with the instrument of thought, not with *that*, whatever it may be, which sets the instrument in motion and regulates its operation. So far, indeed, as there is any connection between physical researches into the nature of the brain or its employment in thought, and our ideas respecting the individuality of the thinker, the evidence seems not of a nature to alarm even the most cautious. Thus, when Mr. Huxley maintains that thought is "the expression of molecular changes in that matter of life which is the source of our other vital phenomena," we are still as far as ever from knowing where resides the moving cause to which these changes are due. We have found that the instrument of thought is moved by certain material connecting links before unrecognized; but to conclude that therefore thought is a purely material process, is no more necessarily just than it would be to conclude that the action of a steam-engine depends solely on the eccentric which causes the alternation of the steam-supply. Again, we need find nothing very venturesome in Prof. Haughton's idea, that "our successors may even dare to speculate on the changes that converted a crust of bread, or a bottle of wine, in the brain of Swift, Molière, or Shakespeare, into the conception of the gentle Glumdalclitch, the rascally Sganarelle, or the immortal Falstaff," seeing that it would still remain unexplained how such varying results may arise from the same material processes, or how the selfsame fuel may produce no recognizable mental results. The brain does not show in its constitution why such differences should exist. "The lout who lies stretched on the tavern-bench," says Wendell Holmes, "with just mental activity enough to keep his pipe from going out, is the unconscious tenant of a laboratory where such combinations are being constantly made as never Wöhler or Berthelot could put together; where such fabrics are woven, such colors dyed, such problems of mechanism solved, such a commerce carried on with the elements and forces of the outer uni-

verse, that the industries of all the factories and trading establishments in the world are mere indolence, and awkwardness, and unproductiveness, compared to the miraculous activities of which his lazy bulk is the unheeding centre." Yet the conscious thought of the lout remains as unlike as possible to the conscious thought of the philosopher; nor will crusts of bread or bottles of wine educe aught from the lout's brain that men will think worth remembering in future ages.

Moreover, we must remember that we have to deal with facts, let the interpretation of these facts be what it may. The relations between mental activity and material processes affecting the substance of the brain are matters of observation and experiment. We may estimate the importance of such research with direct reference to the brain as the instrument of thought, without inquiring by what processes that instrument is called into action. "The piano which the master touches," to quote yet again from the philosophic pages of Holmes's "Mechanism in Thought and Morals," "must be as thoroughly understood as the musical box or clock which goes of itself by a spring or weight. A slight congestion or softening of the brain shows the least materialistic of philosophers that he must recognize the strict dependence of mind upon its organ in the only condition of life with which we are experimentally acquainted; and, what all recognize as soon as disease forces it upon their attention, all thinkers should recognize without waiting for such an irresistible demonstration. They should see that the study of the organ of thought, microscopically, chemically, experimentally, in the lower animals, in individuals and races, in health and in disease, in every aspect of external observation, as well as by internal consciousness, is just as necessary as if the mind were known to be nothing more than a function of the brain, in the same way as digestion is of the stomach."

In considering the growth of the mind, however, in these pages, it appears to me sufficient to call attention to the physical aspect of the subject, without entering into an account of what is known about the physical structure of the brain and the manner in which that structure is modified with advancing years. Moreover, I do not think it desirable, in the limited space available for such an essay as the present, to discuss the various forms of mental power; indeed, this is by no means essential where a general view of mental growth and decay is alone in question. Precisely as we can consider the development and decay of the bodily power without entering into a discussion of the various forms in which that power may be manifested, so we can discuss the growth of the mind without considering special forms of mental action.

Nevertheless, we cannot altogether avoid such considerations, simply because we must adopt some rule for determining what constitutes

mental power. Here, indeed, at the outset, a serious difficulty is encountered. Certain signs of mental decay are sufficiently obvious, but the signs which mark the progress of the mind to its maximum degree of power, as well as the earlier signs of gradually diminishing mental power, are far more difficult of recognition. This is manifest when we consider that they should be more obvious, one would suppose, to the person whose mind is in question, than to any other; whereas it is a known fact that men do not readily perceive (certainly are not ready to admit) any falling off in mental power, even when it has become very marked to others. "I, the Professor," says Wendell Holmes in the "Professor at the Breakfast-table," "am very much like other men. I shall not find out when I have used up my affinities. What a blessed thing it is that Nature, when she invented, manufactured, and patented her authors, contrived to make critics out of the chips that were left! Painful as the task is, they never fail to warn the author, in the most impressive manner, of the probabilities of failure in what he has undertaken. Sad as the necessity is to their delicate sensibilities, they never hesitate to advertise him of the decline of his powers, and to press upon him the propriety of retiring before he sinks into imbecility." Notwithstanding the irony, which is just enough so far as it relates to ordinary criticism, there can be no question that, when an author's powers are failing, his readers, and especially those who have been his most faithful followers, so to speak, devouring each of his works as it issues from his pen, begin to recognize the decrease of his powers before he is himself conscious that he is losing strength. The case of Scott may be cited as a sufficient illustration, its importance in this respect being derived from the fact that he had long been warmly admired and enthusiastically appreciated by those who at once recognized signs of deterioration in "Count Robert of Paris," and "Castle Dangerous."

Yet judgment is most difficult in such matters. We can readily see why no man should be skilled to detect the signs of change in his own mind, since the self-watching of the growth and decay of mind is an experiment which can be conducted but once, and which is completed only when the mind no longer has the power of grasping all the observed facts and forming a sound opinion upon them. But it is even more natural that those who follow the career of some great mind should often be misled in their judgment as to its varying power. For, it must be remembered that the conditions under which such minds are exercised nearly always vary greatly as time proceeds. This circumstance affects chiefly the correctness of ideas formed as to the decay of mental powers, but it has its bearing also on the supposed increase of these powers. For instance, the earlier works of a young author, diffident perhaps of his strength, or not quite conscious where his chief strength resides, will often be characterized by a weakness which is in no true sense indicative of want of mental power. A work by the

same author when he has made for himself a name, when he knows something of the feeling of the public as to his powers, and when also he has learned to distinguish the qualities he possesses—to see where he is strong and where weak—will have an air of strength and firmness not due, or only partially due, to any real growth of his mental powers. But, as I have said, and as experience has repeatedly shown, it is in opinions formed as to the diminution of mental power that the world is most apt to be deceived. How commonly the remark is heard that So-and-so has written himself out, or Such-a-one is not the man he was, when in reality, as those know who are intimate with the author so summarily dismissed, the deterioration, justly enough noted, is due to circumstances in no way connected with mental capacity! The author who has succeeded in establishing a reputation may not have (nay, very commonly has not) the same reason for exerting his powers to the full, as he had when he was making his reputation. He may have less leisure, more company, new sources of distraction, and so on. The earlier work, his *chef-d'œuvre*, let us say, may have been produced at one great effort, no other subject being allowed to occupy his attention until the masterpiece had been completed—the later and inferior work, hastily accepted as evidence that the author's mind no longer preserves its wonted powers, may have been written hurriedly and piecemeal, and subjected to no jealous revision before passing through the press.

Here I have taken literary work as affording typical instances. But similar misapprehensions are common in other departments of mental work. For example, it is related that Newton, long before he was an old man, said of himself that he could no longer follow the reasoning of his own "Principia," and this has commonly been accepted as evidence that his mind had lost power. The conclusion is an altogether unsafe one, as every mathematician knows. It would have been a truly wonderful circumstance if Newton had been able, even only ten or twelve years after his *magnum opus* was completed, to follow its reasoning with satisfaction to his own mind—that is, with the feeling that he still had that grasp of the subject which he had possessed when, after long concentration of his thoughts upon it, he was engaged in the task of exhibiting a summary of his reasoning (for the "Principia" is scarcely more).

I can give more than one instance, in my own experience, of this seeming loss of mastery over a mathematical subject, while in reality the mind has certainly not deteriorated in its power of dealing with subjects of that particular kind. I will content myself with one. It happened that in 1869 I had occasion to examine a mathematical subject of no very great difficulty, but involving many associated relations, and requiring therefore a considerable amount of close attention. At that time I had made myself master, I think I may say without conceit, of that particular subject in all its details. Recently, I had

occasion to resume the study of a part of the subject, in order to reply to some questions which had been asked me. Greatly to my annoyance, I found that I had apparently lost my grasp of it. The relations involved seemed more complex than they had before appeared to me; and I should there and then have dismissed the subject (not having leisure for mere mental experiments) with the feeling that my strength for mathematical inquiries had diminished. But the subject chanced to be one that I could not dismiss, for, though the questions directed to me might have been left unanswered, the time had come which I had assigned to myself (under certain eventualities then realized) for a complete restatement of my views, enforced and reiterated in every possible way, until a certain course depending upon them should have been adopted, or else the discussion of the matter rendered useless by lapse of time. I soon found, after resuming my study of the subject, that it was far more completely within my grasp than before—in fact, on reacquiring my knowledge of its details, the problems involved appeared to me as mere mathematical child's-play.

The great difficulty in judging of the growth and development of the mind consists in the want of any reliable measure of mental strength—any mental dynamometer, so to speak. Our competitive examinations are attempts in this direction, but very imperfect ones, as experience has long since shown. Neither acquired knowledge, nor the power of acquiring knowledge, is any true measure of mental strength. The power of solving mathematical problems is not necessarily indicative even of mathematical power, far less of general mental power. The ordinary tests of classical knowledge, again, have little real relation to mental strength. It may be urged that our most eminent men have, for the most part, been distinguished, at school or university, by either mathematical or classical knowledge, or both. This is doubtless true; but so it would be the case that they would have distinguished themselves above their fellows at public school or university if the heads of these establishments had in their wisdom set Chinese puzzling as the primary test of merit. The powerful mind will show its superiority (in general) in any task that may be assigned it; and, if the test of distinction is to be the skillful construction of Greek and Latin verse, or readiness in treating mathematical problems, a youth of good powers, unless he be wanting in ambition, will acquire the necessary qualifications even though he has no special taste for classical or mathematical learning, and is even perfectly assured that in after-life he will never pen a sapphic or set down an equation of motion.

In passing, I may note that nearly all our attempted measurements of mind depend too much on tests of memory. It is not recognized sufficiently that the part which memory plays in the workings of a powerful mind is subordinate. A good memory is a very useful servant; nothing more. In the really difficult mental processes, memory—

at least what is commonly understood by the term—plays a very unimportant part. Of course a weak memory is an almost fatal obstacle to effective thought; but I am not comparing the worth of a good memory and a bad one, but of an average memory and one exceptionally powerful. I conceive that quite a large proportion of the most profound thinkers are satisfied to exert their memory very moderately. It is, in fact, a distraction from close thought to exert the memory overmuch; and a man engaged in the study of an abstruse subject will commonly rather turn to his book-shelves for the information he requires than tax his memory to supply it. The case resembles somewhat that of the mathematician who from time to time, as his work proceeds, requires this or that calculation to be effected. He will not leave the more engrossing questions that he has in his thoughts, to go through processes of arithmetic, but will adopt any ready resource which leaves him free to follow without check the train of his reasoning.

It would be perhaps difficult to devise any means of readily measuring mental power in examination or otherwise. The memory test is assuredly unsafe; but it would not be easy to suggest a really reliable one. I may remark that only those experienced in the matter understand how much depends on memory in our competitive examinations. Many questions in the examination-papers apparently require the exercise of judgment rather than memory; but those who know the text-books on which the questions are based are aware that the judgment to be written down in answer is not to be formed but to be quoted. So with mathematical problems which appear to require original conceptions for their solution: in nine cases out of ten such problems are either to be found fully solved in mathematical works, or others so nearly resembling them are dealt with that no skill is required for their solution.

I must confess that I am somewhat surprised to find Wendell Holmes, whose opinions on such matters are usually altogether reliable, recommending a test of mental power depending on a quality of memory even inferior to that usually in question in competitive examinations. "The duration of associated impressions on the memory differs vastly," he says, "as we all know, in different individuals. But in uttering distinctly a series of unconnected numbers or letters before a succession of careful listeners, I have been surprised to find how generally they break down, in trying to repeat them, between seven and ten figures or letters; though here and there an individual may be depended on for a larger number. Pepys mentions a person who could repeat sixty unconnected words, forward or backward, and perform other wonderful feats of memory; but this was a prodigy.[1]

[1] "This is nothing to the story told by Seneca of himself, and still more of a friend of his, one Portius *Latro* (*Mendax* it might be suggested), or to that other relation of Muretus, about a certain young Corsican." The note is Holmes's; but there are authen-

I suspect we have in this and similar trials a very simple mental dynamometer which may find its place in education." It appears to me, on the contrary, that tests of the kind should be as little used as may be. Memory will always have an unfair predominance in competitive examinations; but tests which are purely mnemonic, the judgment being in no way whatever called upon, ought not to be introduced, and should be discarded as soon as possible where already in use.[1]

It is worthy of notice that the growth of the mind is often accompanied by an apparent loss of power in particular respects; and this fact is exceedingly important, especially to all who desire to estimate the condition of their own mind. The mental phenomenon called (not very correctly) absence of mind is often regarded by the person experiencing it, and still more by those who observe it in him, as a proof of failing powers. But it often, if not generally, accompanies the increase of mental power. Newton displayed absence of mind much more frequently and to a much more marked degree when his powers were at their highest than in his youth, and not only did instances become much less frequent when he was at an advanced age, but the opposite quality, sensitiveness to small annoyances, began then to be displayed. Even an apparent impairment of the memory is not necessarily indicative of failing mental powers, since it is often the result of an increased concentration of the attention on subjects specially calling for the exercise of the highest forms of mental power —as analysis, comparison, generalization, and judgment. I have already noted that profound thinkers often refrain from exercising the memory, simply to avoid the distraction of their thoughts from the main subject of their study. But this statement may be extended into the general remark that the most profound students, whether of physical science, mathematics, history, politics, or, in fine, of any difficult subject of research, are apt to give the memory less exercise than shallower thinkers. Of course, the memory is exerted to a considerble degree, even in the mere marshaling of thoughts before theories can be formed or weighed. But the greater part of the mental action

ticated instances fully as remarkable as those here referred to. For instance, there is a case of an American Indian who could repeat twenty or thirty lines of Homer which had been read once to him, though he knew nothing of the Greek language. The power of repeating *backward* a long passage after it has been but once read is somewhat similar to that of repeating unconnected numbers, letters, or words This power has been possessed to a remarkable degree by persons in no way distinguished by general ability

[1] It may perhaps occur to the reader that I who write may object to mnemonic tests, because they would act unfavorably if they were applied to my own mental qualities. The reverse is, however, the case. I can recall competitive examinations in which I had an undue advantage over others because my memory chances to be very retentive in one particular respect: In its general nature my memory is about equal, I imagine, to the average, perhaps it is better than the average for facts, and rather below the average for what is commonly called learning "by heart:" but it is singularly retentive for the subject-matter of passages *read overnight.*

devoted to the formation or discussion of theories is only indirectly dependent upon the exercise of memory.

Subject to the considerations suggested above, we may fairly form our opinion as to the general laws of the development of mind, by examining the lives of distinguished men and taking the achievement of their best work, that by which they have made their mark in the world's history, as indicative of the epoch when the mind had attained its greatest development. Dr. Beard, of New York, has recently collected some statistical results, which throw light on the subject of mental growth, though we must note that a variety of collateral circumstances have to be taken into account before any sound opinion can be formed as to the justice of Dr. Beard's conclusions. He states that "from an analysis of the lives of a thousand representative men in all the great branches of human effort, he had made the discovery that the golden decade was between thirty and forty, the silver between forty and fifty, the brazen between twenty and thirty, the iron between fifty and sixty. The superiority of youth and middle life over old age in original work appears all the greater, when we consider the fact that nearly all the positions of honor and profit and prestige—professorships and public stations—are in the hands of the old. Reputation, like money and position, is mainly confined to the old. Men are not widely known until long after they have done the work that gives them their fame. Portraits of great men are a delusion; statues are lies. They are taken when men have become famous, which, on the average, is at least twenty-five years after they did the work which gave them their fame. Original work requires enthusiasm. If all the original work done by men under forty-five were annihilated, the world would be reduced to barbarism. Men are at their best at that time when enthusiasm and experience are most evenly balanced; this period on the average is from thirty-eight to forty. After this period the law is that experience increases but enthusiasm declines. In the life of almost every old man there comes a point, sooner or later, when experience ceases to have any educating power."

There is much that is true, but not a little that is, to say the least, doubtful, in the above remarks. The children of a man's mind, like those of his body, are commonly born while he is in the prime of life. But it must not be overlooked that it is precisely because of the original work done in earlier life that a man as he grows older is commonly prevented from accomplishing any great amount of original work. Nearly the whole of his time is necessarily occupied in maturing the work originated earlier. And again, the circumstance that (usually) a man finds that the work of his earlier years remains incomplete and unsatisfactory, unless the labors of many sequent years are devoted to it, acts as a check upon original investigation. This remark has no bearing, or but slight bearing, on certain forms of literary work; but in nearly every other department of human effort men

advanced in years find themselves indisposed to undertake original research, not from any want of power, but because they recognize the fact that sufficient time does not remain for them to bring such work to a satisfactory issue. They feel that they would have to leave to others the rearing of their mental offspring.

It cannot be questioned, however, that with old age there comes a real physical incapacity for original work, while the power of maturing past work remains comparatively but little impaired. Dr. Carpenter has shown how this may partly be explained by the physical changes which lead in old age to the weakening of the memory; or perhaps we should rather say that in the following passage his remarks respecting loss of memory serve to illustrate the loss of brain-power generally, and especially of the power of forming new ideas, in old age. "The impairment of the memory in old age," he says, "commonly shows itself in regard to new impressions; those of the earlier period of life not only remaining in full distinctness, but even it would seem increasing in vividness, from the fact that the eye is not distracted from attending to them by the continued influx of impressions produced by passing events. The extraordinary persistence of early impressions, when the mind seems almost to have ceased to register new ones, is in remarkable accordance with a law of nutrition I have formerly referred to. It is when the brain is growing that the direction of its structure can be most strongly and persistently" (query, lastingly) "given to it. Thus the habits of thought come to be formed, and those nerve-tracks laid down which (as the physiologist believes) constitute the mechanism of association, by the time that the brain has reached its maturity; and the nutrition of the organ continues to keep up the same mechanism in accordance with the demands upon its activity, so long as it is being called into use. Further, during the entire period of vigorous manhood, the brain, like the muscles, may be taking on some additional growth, either as a whole or in special parts; new tissue being developed and kept up by the nutritive process, in accordance with the modes of action to which the organ is trained. And in this manner a store of 'impressions' or 'traces' is accumulated, which may be brought within the 'sphere of consciousness' whenever the right suggesting strings are touched. But, as the nutritive activity diminishes, the 'waste' becomes more rapid than the renovation; and it would seem that, while (to use a commercial analogy) the 'old-established houses' keep their ground, those later firms, whose basis is less secure, are the first to crumble away—the nutritive activity which yet suffices to maintain the original structure not being capable of keeping the subsequent additions to it in working order. This earlier degeneration of later-formed structures is a general fact perfectly familiar to the physiologist."

One of the most remarkable features of mental development, characteristic, according to circumstances, of mental growth and of mental

decay, is the change of taste for mental food of various kinds. Every one must be conscious of the fact that books, and the subjects of thought, lose the interest they once had, making way for others of a different nature. The favorite author, whose words we read and reread with continually fresh enjoyment in youth, appears dull and uninteresting as the mind grows, and becomes unendurable in advanced years. And this is not merely the effect of familiarity. I knew one who was never tired of reading the works of a famous modern novelist until the age of twenty-five or thereabouts, when it chanced that he was placed in circumstances which caused novel-reading to be an unfrequent occupation, and in point of fact certain works of this author were not opened by him for ten or twelve years. He supposed, when at the end of that time he took up one of these works, that he should find even more than the pleasure he formerly had in reading it, since the story would now have something of novelty for him, and he had once thoroughly enjoyed reading it even when he almost knew the work by heart. But he no longer found the work in the least interesting; the humor seemed forced, the pathos affected, the eloquence false; in short, he had lost his taste for it. In the mean time the works of another equally famous humorist had acquired a new value in his estimation.[1] They had formerly seemed rather heavy reading; now, every sentence gave enjoyment. They appeared now as books not to be merely tasted or swallowed, as Bacon hath it, but "to be chewed and digested." The change here described indicated (in accordance at least with the accepted estimates of the novelist and humorist in question) an increase of mental power. But a distaste for particular writings may imply the decay of mental power. And also, more generally, a tendency to disparagement is a very common indication of advancing mental age. "The old brain," says Wendell Holmes, "thinks the world grows worse, as the old retina thinks the eyes of needles and the fractions in the printed sales of stocks grow smaller."

Another singular effect of advancing years is shown by the tendency to repetition. It is worthy of notice that this peculiar mental phenomenon has been clearly associated with physical deterioration of the substance of the brain, because it may be brought about by a blow or by disease. Wendell Holmes, speaking of this peculiarity, remarks, "I have known an aged person repeat the same question five,

[1] Probably the best means of testing the development of one's own mind consists in comparing the estimate formed, at different times, of the value of some standard work. Of course different classes of writing should be employed to test different faculties of the mind. A good general test may be found in Shakespeare's plays, and perhaps still better in some of Shakespeare's sonnets. As the mind grows, its power of appreciating Shakespeare increases; and the great advantage of this particular test is, that the mind cannot overgrow it. It is like the standard by which the sergeant measures recruits, which will measure men of all heights, not failing even when giants are brought to be measured by it.

six, or seven times, during the same brief visit. Everybody knows the archbishop's flavor of apoplexy in the memory as in the other mental powers. I was once asked to see a woman who had just been injured in the street. On coming to herself, 'Where am I? What has happened?' she asked. 'Knocked down by a horse, ma'am; stunned a little; that is all.' A pause, 'while one, with moderate haste, might count a hundred;' and then again, 'Where am I? What has happened?' 'Knocked down by a horse, ma'am; stunned a little; that is all.'" (Mr. Holmes appears to have sympathized with the patient's mental condition.) "Another pause, and the same question again; and so on during the whole time I was by her. The same tendency to repeat a question indefinitely has been observed in returning members of those worshiping assemblies whose favorite hymn is 'We won't go home till morning.' Is memory then," he proceeds, "a material record? Is the brain, like the rock of the Sinaitic Valley, written all over with inscriptions left by the long caravans of thought, as they have passed year after year through its mysterious recesses? When we see a distant railway-train sliding by us in the same line, day after day, we infer the existence of a track which guides it. So, when some dear old friend begins that story we remember so well—switching off at the accustomed point of digression; coming to a dead stop at the puzzling question of chronology; off the track on the matter of its being first or second cousin of somebody's aunt; set on it again by the patient, listening wife, who knows it all as she knows her well-worn wedding-ring—how can we doubt that there is a track laid down for the story in some permanent disposition of the thinking-marrow?"

We seem to recognize here a process of change in the brain corresponding to that which takes place in the body with advancing years—the induration of its substance, so that it loses flexibility, and thus, while readily accomplishing accustomed work, is not readily adapted for new work. Our old proverb, "You can't teach an old dog new tricks," indicates, coarsely enough, but justly, the peculiarity, as well mental as bodily, to which I refer. There is not a loss of power, but a loss of elasticity. We see aged men working well in the routine work to which they have been accustomed, but failing where there is occasion for change either of method or of opinion. Again, one recognizes this peculiarity in the scientific worker, whence perhaps we may regard it as a fortunate circumstance that the tendency of the aged mind accords with its faculties, so that old men do not readily undertake new work. Perhaps no more remarkable instance could be cited of the combination I refer to—the possession of power on the one hand, and the want of elasticity on the other—than the remarkable papers on the universe, written by Sir W. Herschel, in the years 1817 and 1818, that is, in his seventy-ninth and eightieth years. We find the veteran astronomer proceeding in the path which, more than forty years before,

he had marked out for himself; but the very steadiness and strength of purpose with which he pursues it indicate the degree to which his mind had lost its wonted elasticity. In 1784 and 1785 he was traversing a portion of the same road. But then he was in the prime of his powers, and accordingly we recognize a versatility which enabled him to test and reject the methods of research which presented themselves to his mind. It was in those years that he invented his famous method of star-gauging, which our text-books of astronomy preposterously adopt as if it were an established and recognized method of scientific research. But Herschel himself, after trying it, and satisfying himself that it was unsound in principle, abandoned it altogether. In 1817 he adopted a method of research equally requiring to be tested, and, in my conviction, equally incapable of standing the test; but he now worked upon the plan he had devised, without subjecting it to any test. Nay, results which only a few years before he would certainly have rejected—for he did then actually reject results which were open to the same objection—passed muster in 1817 and 1818, and are recorded in his papers of those dates without comment. We may recognize another illustration of the loss of elasticity with advancing years, in the obstinacy, one may even say the perversity, with which Sir Isaac Newton, in the latter years of his life, adhered to opinions on certain points where, as has since been shown, he was unquestionably wrong, and where, had he possessed his former mental versatility, he must have perceived as much. Compare this with his conduct in earlier years, when for nineteen years he freely abandoned his theory of gravitation—though he had fully recognized its surpassing importance—simply because certain minute details were not satisfactorily accounted for. Many other instances might be cited, were it worth while, to show how the mind commonly changes when approaching an advanced age, in a manner corresponding to that bodily change—that stiffness and want of elasticity, without any marked loss of power—which comes on with advancing years. That old age does not necessarily involve any loss of power for routine work, has been clearly shown in the lives of many eminent men of our own era. The present Astronomer Royal for England affords a remarkable illustration of the fact, as also of the associated fact that new work is not easily achieved, nor an old mistake readily admitted or corrected at an advanced age.

It is well pointed out by Dr. Beard, in the lecture to which I have already referred, that "we must not expect to find at one age the mental qualifications due to another age—we must not look for experience and caution in youth, or for suppleness and versatility in age. We ought also to apportion to the various ages of a man the kind of work most suitable to them. Positions which require mainly enthusiasm and original work should be filled by the young and middle-aged; positions that require mainly experience and routine work, should be

filled by those in mature and advanced life, or (as in clerkships) by the young who have not yet reached the golden decade. The enormous stupidity, and backwardness, and red-tapeism, of all departments of governments everywhere, are partly due to the fact that they are too much controlled by age. The conservatism and inferiority of colleges are similarly explained. Some of those who control the policy of colleges—presidents and trustees—should be young and middle-aged. Journalism, on the other hand, has suffered from relative excess of youth and enthusiasm."

Before passing from the lecture of Dr. Beard, I shall venture to quote the remarks which he makes on the evidence sometimes afforded of approaching mental decay by a decline in moral sensitiveness. "Moral decline in old age," he says, "means—'Take care; for the brain is giving way.' It is very frequently accompanied or preceded by sleeplessness. Decline of the moral faculties, like the decline of other functions, may be relieved, retarded, and sometimes cured by proper medical treatment, and especially by hygiene. In youth, middle age, and even in advanced age, one may suffer for years from disorders of the nervous system that cause derangement of some one or many of the moral faculties, and perfectly recover. The symptoms should be taken early, and treated like any other physical disease. Our best asylums are now acting upon this principle, and with good success. Medical treatment is almost powerless without hygiene. Study the divine art of taking it easy. Men often die as trees die, slowly, and at the top first. As the moral and reasoning faculties are the highest, most complex, and most delicate development of human nature, they are the first to show signs of cerebral disease. When they begin to decay in advanced life, we are generally safe in predicting that, if these signs are neglected, other functions will sooner or later be impaired. When conscience is gone, the constitution is threatened. Everybody has observed that greediness, ill-temper, despondency, are often the first and only symptoms that disease is coming upon us. The moral nature is a delicate barometer, that foretells long beforehand the coming storm in the system. Moral decline, as a symptom of cerebral disease, is, to say the least, as reliable as are many of the symptoms by which physicians are accustomed to make a diagnosis of various diseases of the bodily organs. When moral is associated with mental decline in advanced life, it is almost safe to make a diagnosis of cerebral disease. . . . Let nothing deprive us of our sleep. Early to bed and late to rise make the modern toiler healthy and wise. The problem for the future is to work hard, and at the same time to take it easy. The more we have to do, the more we should sleep. Let it never be forgotten that death in the aged is more frequently a slow process than an event; a man may begin to die ten or fifteen years before he is buried."

When mental decay is nearing the final stage, there is a tendency

to revert to the thoughts and impressions of former years, which is probably dependent on the processes by which the substance of the brain is undergoing decay. The more recent formations are the first, as we have seen, to crumble away, and the process not only brings to the surface, if we may so speak, the earlier formations—that is, the material records of earlier mental processes—but would appear to bring those parts of the cerebrum into renewed activity. Thus, as death draws near, men "babble of green fields," as has been beautifully said, though not by Shakespeare, of old Jack Falstaff. Or less pleasant associations may be aroused, as we see in Mrs. Grandmother Smallweed, when "with such infantine graces as a total want of observation, memory, understanding, and intellect, and an eternal disposition to fall asleep over the fire and into it," she "whiled away the rosy hours" with continual allusions to money.

The recollections aroused at the moment of death are sometimes singularly affecting. None can read without emotion the last scenes of the life of Colonel Newcome. I say the last scenes, not the last scene only, though that is the most beautiful of all. Every one knows those last pages by heart, yet I cannot forbear quoting a few sentences from them. "'Father!' cries Clive, 'do you remember Orme's "History of India?"' 'Orme's History, of course I do; I could repeat whole pages of it when I was a boy,' says the old man, and began forthwith: "'The two battalions advanced against each other cannonading, until the French, coming to a hollow way, imagined the English would not venture to pass it. But Major Lawrence ordered the sepoys and artillery—the sepoys and artillery to halt, and defend the convoy against the Morattoes.' Morattoes, Orme calls them. Ho! ho! I could repeat whole pages, sir.'" Later, "Thomas Newcome began to wander more and more. He talked louder; he gave the word of command, and spoke Hindoostanee, as if to his men. Then he spoke words in French rapidly, seizing a hand which was near him, and crying, 'Toujours, toujours.' But it was Ethel's hand which he took. . . . Some time afterward, Ethel came in with a scared face to our pale group. 'He is calling for you again, dear lady,' she said, going up to Madame de Florac, who was still kneeling. 'And just now he said he wanted Pendennis to take care of his boy. He will not know you.' She hid her tears as she spoke. She went into the room, where Clive was at the bed's foot; the old man within it talked on rapidly for awhile; then again he would sigh and be still: once more I heard him say hurriedly, 'Take care of him when I'm in India,' and then with a heart-rending voice he called out, 'Léonore, Léonore!' She was kneeling at his side now. The patient's voice sank into faint murmurs; only a moan now and then announced that he was not asleep. At the usual evening hour the chapel-bell began to toll, and Thomas Newcome's hands outside the bed feebly beat time. And, just as the last bell struck, a peculiar, sweet smile shone over his face, and he

lifted up his head a little, and quickly said, 'Adsum!' and fell back. It was the word we used at school when names were called, and lo, he, whose heart was as that of a little child, had answered to his name, and stood in the presence of The Master."

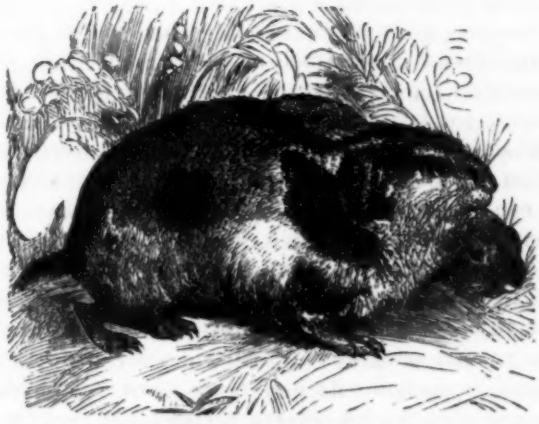
Sadder than death is it, however, when the brain perishes before the body. "How often, alas, we see," says Wendell Holmes, "the mighty satirist tamed into oblivious imbecility; the great scholar wandering without sense of time or place, among his alcoves, taking his books one by one from the shelves and fondly patting them: a child once more among his toys, but a child whose to-morrows come hungry, and not full-handed—come as birds of prey in the place of the sweet singers of morning. We must all become as little children if we live long enough; but how blank an existence the wrinkled infant must carry into the kingdom of heaven, if the Power that gave him memory does not repeat the miracle by restoring it!"—*Cornhill Magazine.*

AN EPISODE ON RATS.

THE Norway rat, of which we wish to say a few words, is the *Lemming*, a species of the mouse-tribe, somewhat smaller than the Guinea-pig, to which in form it bears a considerable resemblance, only the head and body are flatter. Its length is about six inches, of which the short stump of a tail forms half an inch. It is black in color, mottled with tawny spots, which vary in their disposition in different individuals, and the belly is white, with a slight tinge of yellow. The fore-legs are short and strong, and the hind-legs are nearly one-half longer than the former, enabling it to run with considerable speed. The feet are armed with strong hooked claws, five in number, enabling it to burrow in the earth, and among the frozen snows of its native region. Its cheeks are blanched, and it sports a pair of long light whiskers, and its eyes, though small, are beautifully black and piercing. The lip is divided, and the ears are small and sharply pointed. As its home borders on the region of eternal snow, in the valleys of the Kolen Mountains, which separate Sweden from Nordland, its hair is both thick and soft, and becomes almost white during the long and cheerless winter of these inhospitable regions. The skin is much thinner than in any of its congeners. When enraged it gives utterance to a sharp yelp, similar to that of a month-old terrier-whelp.

It is a lively little fellow, when met with in its native haunts, during the short summer—now sitting on its haunches nibbling at a piece of lichen, or the catkins of the birch, which it conveys to its mouth with its fore-paws, after the manner of the squirrel, or engaging in a romp with its fellows, popping in and out of its burrow in the earth

where it sleeps and rears its young, of which the female has two or three litters annually, numbering from five to seven in each. It is a most audacious little fellow, and fears neither man nor beast, refusing to give way save on the compulsion of superior force. Travelers speak of having seen them frisking about in hundreds in their native forests, when they dispute the path even with man. From the vantage-ground of the mounds of earth at the entrance to their burrows, they sit on their beam-ends and scan the intruders with comical gravity. If the traveler has a dog with him, unhappily ignorant of the ways of this cool and impudent *varmint*, he will likely advance with the easy nonchalance of his tribe to smell the odd little animal—which betrays no fear at his approach—to be rewarded by a sharp and trenchant bite on the nose; a reception so sudden and unexpected that it is ten chances to one against his prosecuting his investigations further, for a dog is too well bred to attack any strange living object which awaits his approach.



LEMMING, OR NORWAY RAT.

Unlike many of its congeners, the lemming does not provide a sufficient store of food to last it through the long winter, when the earth is covered with snow, and, as it does not hibernate, it is driven to many a hard shift in its struggle for a subsistence. It devours the bark of trees and small twigs, and drives tunnels through the snow, along the surface of the ground, eating every shred of vegetation it meets with. These food-burrows are all connected with a main burrow, leading to its home in the earth, which is ventilated by a hole driven obliquely through the snow to the surface. These air-shafts guide the arctic fox and the ermine to their whereabouts, and they devour many of them, while kites and other predaceous birds are ever on the watch to pick them up when they emerge upon the surface. The natives of these regions kill and eat them during summer, when they are in good condition; and a traveled friend of ours, who has

partaken of its flesh, speaks of it as a most valuable addition to their scanty *cuisine*. When captured young, it is easily tamed and becomes an interesting pet. We saw one once in the possession of a Montrose skipper, which allowed itself to be handled and fed out of the hand, but it had an awkward habit of fixing its incisors into the fingers of an incautious admirer on the smallest provocation. During summer they swarm with vermin to such an extent that, although when examined singly they can scarcely be discerned by the naked eye, they change the color of the animal to a dull red.

The lemming multiplies so rapidly that in the course of ten or twelve seasons food becomes scarce, and, on the approach of some winter when the food-question has become one of life or death, the overstocked market is relieved by an expedient unparalleled in its nature among four-footed animals. This singular little creature is so local in its habits, that, unless under the circumstances we are about to narrate, it never leaves the mountain-regions to establish itself on the plains, where food is more abundant.

The inhuman suggestion of a modern writer that our paupers should be packed into rotten ships, which should be sent out to sea and scuttled, is something like the method adopted by the lemmings themselves to avert the famine which threatens to annihilate the entire species. When the time for the settlement of the question of partial extermination for the benefit of the race, or total extermination by starvation, can no longer be delayed, they assemble in countless thousands in some of the mountain valleys leading into the plains, and, the vast army of martyrs being selected, they pour across the country in a straight line, a living stream, often exceeding a mile in length, and many yards in breadth, devouring every green thing in their line of march; the country over which they have passed looking as if it had been ploughed, or burned with fire. They march principally by night, and in the morning, resting during the day, but never seek to settle in any particular locality, however abundant food may be in it, for their final destination is the distant sea, and nothing animate or inanimate, if it can be surmounted, retards the straight onward tide of their advance.

When the reindeer gets enveloped in the living stream, they will not even go round its limbs, but bite its legs until, in its agony and terror, it plunges madly about, crushing them to death in hundreds, and even killing them with its teeth. If a man attempts to stem the living torrent, they leap upon his legs; and, if he lay about him with a stick, they seize it with their teeth, and hold on to it with such determined pertinacity that he may swing it rapidly round his head without compelling them to loosen their hold. If a corn or hay rick be in the way, they eat their way through it; and, on arriving at the smooth face of a rock, they pass round it, forming up in close column again on the other side. Lakes, however broad, are boldly entered, and the

passage attempted; and rivers, however deep and rapid, are forded, impediments in the water being as boldly faced as those on shore. They have been known to pass over a boat, and to climb on to the deck of a ship, passing, without stop or stay, into the water on the further side.

Their natural instincts are not in abeyance during this migration, as females are frequently seen accompanied by their young, and carrying in their teeth some one which had succumbed to the fatigues of the march, which might not be stayed until the helpless one was recruited.

Foxes, lynxes, weasels, kites, owls, etc., hover on their line of march and destroy them in hundreds. The fish in the rivers and lakes lay a heavy toll upon them, and vast numbers are drowned, and die by other accidents in "flood and field;" but the survivors, impelled by some irresistible instinct, press onward with no thought of stopping, until they lose themselves in the sea, sinking in its depths, as they become exhausted, in such numbers that for miles their bodies, thrown up by the tide, lie putrefying on the shore. Comparatively few ever return to their native haunts, but there can be no doubt that some do so, as they have been seen on the return, pursuing their backward journey in the same fearless and determined manner as their advance.

The peasants witness this dread incursion with terror. Until lately they believed that the vast horde was rained from heaven as a punishment for their sins, and during the time of their passage they used to assemble in the churches, the priests reciting prayers specially composed for such visitations. It was also believed that the reindeer ate them, and that they so poisoned the ground they passed over that they would not eat on it for a considerable time. As we have seen, the reindeer bites them with its teeth in its agony and terror, and the complete sweep they make of every blade of grass on their line of march satisfactorily accounts for its declining for a time to graze upon it.

A recent writer tells us that, in addition to this wholesale migration, which takes place about twice during a quarter of a century, smaller migrations occur, in which many are killed, while others live to return to their haunts; but as there are several species of lemmings spread over the northern regions of both the Old and the New World, he may allude to another variety than the one we have been dealing with, which is the *Mus lemmus* of Linnæus and Pallas.

The superstitious notions and wonderful reports once prevalent with regard to the lemming, as recorded by old writers, are not without interest. Olaus Magnus says:

"In the foresaid Helsingia, and provinces that are near to it, in the diocese of Upsal, small beasts with four feet, that they call Lemmar or Lemmus, as big as a rat, with a skin diverse-colored, fall out of the ayr in tempests and sudden storms; but no man knows from whence they come—whether from the re-

moter islands, and are brought hither by the wind, or else they breed of feculent matter in the clouds; yet this is proved, that so soon as they fall down there is found green grass in their bellies not yet digested. These, like locusts, falling in great swarms, destroy all green things, and all dyes they bite on, by the venome of them. This swarm lives so long as they feed on new grass. Also they come together in troops like swallows that are ready to fly away; but at the set time they either dye in heaps with a contagion of the earth (by the corruption of them the ayr grows pestilentiall and the people are troubled with vertigos or the jaundice); or they are devoured by beasts called commonly lekeirt or hermalins, and these Ermines grow fat thereby, and their skins grow larger."

Schœffer, whom we next cite, believed that

"They sometimes make war, and divide themselves into two armies along the lakes and meadows. They seem likewise to commit suicide, for they are found suspended in the branches of trees; and they probably throw themselves in troops into waters, like the swallows."

Although prepared to believe that they hanged themselves, he did not believe that they were bred in the clouds. He says:

"Wormius thinks plainly that they are bred in the clouds; but the learned Isaac Rossius, in his notes to Pomponius Mela, corrects him and says, the reason why these animals are supposed to fall from the clouds is, because they used not to appear, but immediately after rain they creep out of their holes, either for that they are filled with water, or because this creature thrives much in rain, which opinion seems most probable to me."

Pontoppidan, writing at a later period, says:

"They multiply very fast by what we see of them, though, God be praised, but seldom, i. e., about once or twice in twenty years, when they come from their peculiar abodes. At these times they gather in great flocks together, consisting of many thousands, like the hosts of God, to execute his will—i. e., to punish the neighboring inhabitants by destroying the seed, corn, and grass; for when this flock advances they make a visible pathway on the earth or ground, cutting off all that is green, and this they have power and strength to do till they reach their appointed bounds, which is the sea, in which they swim a little about, and then sink and drown."

Pontoppidan, who had never seen the lemming alive, although he collected a large amount of interesting information, credible and incredible, regarding it, notes a holiday held in his time throughout Bergen, termed a mouse-festival, which had so far degenerated from its ancient purpose, that the peasants put on their holiday clothes and went to sleep. In former times the day was kept as a solemn fast, "to avert the plague of lemen and other mice, which some pretend have been used to fall down formerly from the clouds."

Wormius, in his treatise on the lemming, gives an exorcism used on such occasions, of which the following is a translation:

"I exorcise you, pestiferous worms, mice, birds, locusts, or other animals, by God the Father Almighty, and Jesus Christ his Son, and the Holy Ghost

proceeding from both, that you depart immediately from these fields, or vineyards, or waters, and dwell in them no longer, but go away to those places in which you can harm no person; and on the part of the Almighty God, and the whole heavenly choir, and the holy Church of God, cursing you whithersoever ye shall go, daily wasting away and decreasing until no remains of you are found in any place, unless necessary to the health and use of man, which may He vouchsafe to do who shall come to judge the living and the dead and the world by fire. Amen."

Traveling rapidly and by night, their sudden irruption into a locality, together with the complete destruction of the field and garden crops, tended to make the ignorant peasantry look upon them as a special visitation from Providence for their sins, and will readily account for the extraordinary notions held regarding them.

Many animals migrate from place to place, or take possession of new territory, when food becomes scarce; but we have only one other instance of a living creature migrating in vast numbers to certain destruction, and that is the locust. When their numbers increase beyond the food-producing powers of their natural habitat, they pour in countless millions into the colder regions beyond, smothering each other in their flight, until the ground is covered with their dead bodies to the depth of several inches, and water-courses are choked up by them, until the air is tainted with the smell of their putrid bodies for miles. None of them ever return whence they came. Their course is always onward, until those that escape death by accident are killed by the first cold weather they encounter. And in this way Nature compels, from time to time, a vast body of these creatures to an act of self-destruction in order that the species may not be annihilated. —*Abridged from Temple Bar.*

THE PRIMARY CONCEPTS OF MODERN PHYSICAL SCIENCE.

By J. B. Stallo.

IV.—Inertia and Force.

IF we look for the speculative background of modern physical theories, we find something like this: Originally there was created, or somehow came to be, an indefinite number of absolutely hard and unchangeable particles of matter. There was also created, or somehow came to be, a number of forces, equally unchangeable—the force of attraction, the force of cohesion, heat, electric and magnetic forces, and so on. The forces began to act and continue to act upon the particles of matter, producing inorganic as well as organic forms. These particles and forces are ultimate facts of experience as well as of thought;

and the action of the forces upon the material particles is likewise an ultimate empirical datum, and therefore inexplicable. Force and matter, though presupposing each other in action, are fundamentally disparate; they are essentially distinct, and mutually irreducible entities. Matter, as such, is passive, dead; all motion or life is caused by force; and the only possible solution of the problems of physiology, no less than of physics and chemistry, consists in the enumeration of the forces acting upon the material particles, and in the exact quantitative determination of the effects produced by their action.

This statement of the tenets of the prevailing physical philosophy, to be exact, requires at most two qualifications. In the first place, the recent doctrine of the correlation and mutual convertibility of the physical forces, as a part of the theory of the conservation of energy, has shaken, if not destroyed, the conception of a multiplicity of independent original forces. And, in the second place, physiologists, like Du Bois-Reymond, recognize force as the invariable concomitant, if not the essential attribute of matter, and assume that to every constant primordial mass belongs a constant primordial quantity of force, so that the problem of physics, chemistry, and physiology, resolves itself into the quantitative determination of the mechanical interactions of material constants primarily endowed with forces acting equally in all directions, or, as they express it, constant central forces.

I have endeavored, thus far, to show that there are no absolute constants of mass; that both the hypothesis of corpuscular "atoms" and that of "centres of force" are growths of a confusion of the intellect which mistakes *conceptual* elements of matter for *real* elements; that these elements—force and mass, or force and inertia—are not only inseparable, as is conceded by the more thoughtful among modern physicists (or, as they usually, but inaccurately express it, that there is no force without matter, and no matter without force), but that neither of these elements has any reality as such, each of them being simply the conceptual correlate of the other, and thus the condition both of its realization in thought and of its objectivation to sense. The tendency to deal with these elements as separate and separately real entities is so irrepressible, however, that it is necessary to subject them to still further discussion, in order to clear up the prevalent confusion in regard to them.

Newton's original definition of inertia was in terms of force. According to him ("Principia," Definitio III.), "there is inherent in matter a force, a power of resistance, in virtue of which every body, as far as in it lies, perseveres in a state of rest, or of uniform rectilinear motion." In the definitions since Newton's time, the term "force" has usually been avoided. Thus Young ("Mechanics," p. 117) defines inertia as "the incapability of matter of altering the state into which it is put by any external cause, whether that state be rest or motion;" and similarly Whewell ("Mechanics," p. 245), as "the quantity of *matter*

considered as resisting the communication of motion." As is readily seen, all these definitions imply, nevertheless, that matter can be moved or changed only from without, by forces external to matter itself. Newton expressly ("Principia," Definitio IV.) speaks of force as "*impressed* upon a body, and as exerted upon it to change its state of rest or uniform motion in a straight line."

There is little difficulty in understanding how this language, in connection with the etymological import of the word "inertia," led to the assumption that matter is essentially passive, or, as it is commonly expressed, dead. There are other reasons for this assumption, connected with the evolution, not only of scientific concepts, properly so called, but of cosmological ideas, to which I shall have occasion, perhaps, to recur in the sequel; indeed, Newton's definitions which I have just cited are simply instances of the intellectual postulates of his time. And the mathematical treatment of mechanical problems, from the nature of its methods, necessitates the fiction that force and mass are separate and distinct terms. In general, it may be said that the assumption of the absolute passivity of matter is one of those errors which are inevitable in the progress of knowledge—one of the "clay moulds in which the bells of scientific truth are cast." But the perpetuation of this error is one of the most fatal impediments to real scientific progress in our day, and is fruitful of vagaries which are wholly incommensurable with the real state of modern scientific knowledge. Thus, Prof. Philip Spiller, the author of a very serviceable manual of physics, and a prolific writer on scientific subjects, has recently published a cosmological treatise,[1] whose theorems are founded upon the express proposition (*op. cit.*, p. 4) that "no material constituent of a body, no atom, is in itself originally endowed with force, but that every such atom is absolutely dead, and without any inherent power to act at a distance." It appears from the further contents of Spiller's treatise, that he not only denies force to the atoms taken singly, but that he also denies the possibility of their mutual action. He is driven, therefore, to the assertion of the independent substantiality of force; and, accordingly, he assumes force to be an all-pervading *quasi*-material presence—as he terms it, an "incorporeal matter" (*unkoerperlicher Stoff*). In utter disregard of the fundamental correlation of force and mass, Spiller identifies his force-substance with the ordinary luminiferous ether, so that this phantom, which, in the view of other physicists, is not only imponderable, but destitute of cohesive, chemical, thermal, electric, and magnetic forces (which, indeed, *must be* destitute of them if it is to serve as the mere substratum of these various modes of motion)—which therefore is, if possible, still more "dead" than ordinary ponderable matter—now suddenly, without changing its name, and without ceasing to be the substratum of luminar and other undulations, comes to be the very quintessence of all possible energy.

[1] "Der Weltaether als Kosmische Kraft," Berlin, Denicke's Verlag, 1873.

It may be said here, parenthetically, that all these recent attempts (to one of which, by Prof. Challis, I had occasion to refer in my second paper) to construe the apparent attractions of bodies as cases of ethereal pressure and propulsion are simply returns to the state of scientific anarchy which prevailed in celestial mechanics before Newton's time. Prof. Spiller is evidently unaware that his theory—according to which, force is an "incorporeal matter"—is nothing but a reproduction of Kepler's speculations (not to speak of the Cartesian and Leibnitian theories to which I have already alluded), in which the vortices supposed to carry the planets along with them were asserted to be an "immaterial species," capable of overcoming the inertia of bodies. It is plain that this "immaterial species" is the same wooden iron which Spiller exhibits under the name of "incorporeal matter," the only difference being that the absurdity of Kepler's chimera was less glaring in the hazy dawn of the mechanical notions of his time, than the extravagance of Spiller's conceit in the light of the scientific atmosphere of our day.

It is almost superfluous to say to the intelligent reader of these papers that Spiller's "dead matter" is a nonentity, inasmuch as we know nothing of material reality except through its action. And it is hardly worth while to point out in detail that the hypothesis of dead atoms is not only inadmissible, but wholly useless. Unchangeable particles destitute of gravity and all other force, even if the action of force upon them were conceivable, must be equally acted upon from all sides by the omnipresent ether, and could, therefore, in no wise help to establish differences of density, or other differences not contained in or evolvable from the ether itself. They could not even add to the extension of a body, much less to its hardness, being wholly without the power of resistance; but, waiving this, and granting for a moment that extension without resistance is possible, they would simply be bubbles of void space encysted in the universal ether, and to the differentiation of this ether alone all the phenomena of the material world would be due.

The truth is, that absolutely passive, dead matter is as unknown in experience as it is inconceivable in thought. Every particle of matter of which we have any knowledge attracts every other particle in conformity to the law of gravitation; and every material element exerts chemical, electrical, magnetic, thermic, and similar forces upon other elements which in respect to these forces are its correlates. The whole presence of matter to the senses consists in the manifestation of power, in the exhibition of force. All this has been very clearly seen and very explicitly stated by numerous physicists;[1] but, unfortunately, by most of them it has been speedily lost sight of in their ulterior speculations.

In what sense, then, can *inertia* be truly predicated of matter?

[1] Among those whose comprehension of this is clear, is M. Comte; his observations upon the subject ("Philosophie Positive," tome i., p. 375, *et seq.*) merits attentive perusal.

The answer to this question will suggest itself at once to those who have properly apprehended the principle of the essential relativity of all material existence. A material object is, in every one of its aspects, but one term of a relation; its whole being is a presupposition of correlates without; all things are, figuratively speaking (if I may resort to such a figure without incurring the charge of illustrating *obscurum per obscurius*) shadows of each other. Every change of a body, therefore, presupposes a corresponding change in its correlates. If the state of any material object could be changed without a corresponding change of state in other objects without, this object would, to that extent, become absolute. But this is utterly unthinkable, and therefore utterly impossible, as we have already seen. At the same time it is also evident that, while every change of a body is thus conditioned by changes without, these latter changes are equally conditioned by it; that all material action, therefore, is mutual; that reaction is invariably equal to action. A corollary from, or rather an application of this is the well-known theorem that the forces within a body or conservative system can alter only the positions of its constituent parts, but cannot change the position of the body as a whole; and that, whenever such an internal change takes place, the momentum accruing in one direction has its counterpart in an equal momentum accruing in the opposite direction. If we apply this theorem to the universe as a whole, i. e., as a single dynamical system, and if we bear in mind that, mechanically speaking, all force properly so called, i. e., all potential energy, is energy of position, we see at once that whatever energy is spent in actual motion is gained in position—that the system, therefore, is absolutely conservative; and we are thus led, by a very simple approach, to the principle of the conservation of energy.[1]

After this summary discussion of the first conceptual element of matter, *inertia*, I proceed to the consideration of the other element, *force*. In the canonical text-books on physics, force is defined as the *cause* of motion. "Any cause," says Whewell ("Mechanics," p. 1), "which moves or tends to move a body, or which changes or tends to change its motion, is called force." Similarly Clerk Maxwell ("Theory of Heat," p. 83): "Force is whatever changes or tends to change the motion of a body by altering either its direction or its magnitude." Taking either of these definitions as correctly representing the re-

[1] If the term "force" is restricted, as it ought to be, to the designation of potential energy, or mere tension, the expression "persistence or conservation of force" becomes inaccurate; for the sum of the forces in the universe, in this sense, is by no means constant. The "persistence of *force*," or, more properly, the "conservation of energy," simply imports that the sum of actual or kinetic energy (energy in motion) and potential energy (energy of position or energy in tension) in the material universe is invariable. This, as is shown in the text, is but an amplification of the theorem that in any limited conservative system the sum of the potential and kinetic energies of its parts is never changed by their mutual actions.

ceived theories of physical science respecting the nature of force, it is manifest, irrespective of the considerations which I have presented in this and the preceding essays, that force is not an individual thing or distinct entity which presents itself directly either to observation or to thought, but that, so far as it is taken as a definite and unital term in the operations of thought, it is purely a fiction of the intellect. The cause of motion, or change of motion, in a body is simply the condition or group of conditions upon which this motion depends; and this condition, or group of conditions, as we have already seen, is always a corresponding motion, or change of motion, in the bodies, outside of the moving body, which are its correlates. Otherwise expressed, force is a mere inference from the motion itself under the universal conditions of reality, and its measure, therefore, is simply the effect for which it is postulated as a cause; it has no other existence. The only reality of force and of its action is the correspondence between physical phenomena in conformity to the principle of the essential relativity of all material existence.

That force has no independent reality is so plain and obvious that it has been proposed by some thinkers to abolish the term force, like the term cause, altogether. However desirable this might be in some respects, it is impossible, for the reason that the concept "force," when properly interpreted in terms of experience, is valid, and, if its name were abolished, it would instantly reappear under another name. There is hardly any concept which has not, in science as well as in metaphysics, given rise to the same confusion which prevails in regard to "force" and "cause;" and the blow leveled at these would demolish all concepts whatever. Nevertheless, it is of the greatest moment, in all speculations concerning the interdependence of physical phenomena, never to lose sight of the fact that the reality of force is purely conceptual, and that it is not a distinct and individual tangible or intangible entity.

How imperfectly all this is understood by the physicists of our time appears at once upon an examination of elementary treatises as well as original disquisitions on physical science. Thus the relation of force to mechanical motion is constantly spoken of as a "fact" ascertained by experience and verified experimentally beyond the possibility of question. In a learned article by J. Croll, published in the July number, 1872, of the *Philosophical Magazine* ("What determines Molecular Motion," etc., *Phil. Mag.*, fourth series, vol. xl., p. 37), it is said: "In regard to the first question (what produces motion) there is no diversity of opinion. All agree that what produces change or causes motion is force." The obvious meaning of this is that it might possibly admit of question whether material change or motion is produced by force or something else, and that physicists, on the whole, have come to the conclusion that it is produced by force. Such a question ought, indeed, to be solemnly pondered by grave

philosophers! It is like the question which Simon Sachs, in his despair, propounded to the gods: 'Who will assure us that the star, which the astronomers regard as Uranus, is Uranus in fact?'"[1]

Physicists generally, however, are in still greater confusion as to the nature of force in another respect. Bodies are said to be *endowed* with a definite quantity of force, if not with a given number of forces; it is assumed that to every particular body or particle belongs, or in such body or particle in and by itself is inherent, an invariable measure of energy. This statement, besides involving the confusion just noted as to the reality of force, implies the assumption that force can be an attribute or concomitant of a single body or particle as such. This assumption ignores the fact, which is otherwise well known to physicists, that the very conception of force depends upon the relation between two terms at least. "Every force," says Clerk Maxwell ("Theory of Heat," p. 94), "acts between two bodies or parts of bodies." A "constant central force," therefore, as belonging to an individual atom in and by itself, is an impossibility.

We have now arrived at a point where it will be profitable to recur for a moment to the proposition of Du Bois-Reymond referred to at the beginning of my first paper, that the whole problem of physical science consists in "the resolution of all changes in the material world into motions of atoms caused by their constant central forces." The entire passage in Du Bois-Reymond's text, from which I extracted two sentences, reads as follows: "Natural science—more accurately expressed, scientific cognition of Nature, or cognition of the material world by the aid and in the sense of theoretical physical science—is a reduction of the changes in the material world to motions of atoms caused by central forces independent of time, or a resolution of the phenomena of Nature into atomic mechanics. It is a fact of psychological experience that, whenever such a reduction is successfully effected, our craving for causality is, for the nonce, wholly satisfied. The propositions of mechanics are mathematically representable, and carry in themselves the same apodictic certainty which belongs to the propositions of mathematics. When the changes in the material world have been reduced to a constant sum of potential and kinetic energy, *inhering in a constant mass of matter*, there is nothing left in these changes for explanation.

"The assertion of Kant in the preface to the 'Metaphysical Rudiments of Natural Science,' that 'in every department of physical science there is only so much science, properly so called, as there is mathematics,' is to be sharpened by substituting 'mechanics of atoms' for 'mathematics.' This was evidently his own meaning when he denied the name 'science' to chemistry. It is not a little remarkable that in our time chemistry, since it has been constrained, by the dis-

[1] "Das Sonnensystem, oder neue Theorie vom Bau der Welten, von Simon Sachs," p. 193, C. Fechner.

covery of substitution, to abandon the old electro-chemical dualism, has seemingly taken a retrograde step in its advance toward science in this sense. The resolution of all changes in the material world into motions of atoms caused by their constant central forces would be the completion of natural science."

How do these sentences of one of the foremost physicists of the day now present themselves to our view in the light of the preceding discussion? Atoms are absolute physical constants, or constants of mass; and I have shown that there are, and can be, no absolute constants of mass. And it is evident now, I trust, that there are similarly no constant central forces belonging to, or inherent in, constants of mass as such. Both the constants of mass and the constant forces assumed to belong to them are simply parts of the scaffolding of the intellect, when it seeks to subject the phenomena of the material world to exact mathematical determination. They are, as I have already intimated, instrumental fictions which are, for the moment, indispensable by reason of the inability of the intellect to deal with phenomena otherwise than singly and under a definite aspect. In order to effect a quantitative determination of material action, the mathematician is constrained to insulate the conceptual elements of matter and to treat them as separate and distinct terms. He is constrained to represent as discrete what is continuous, and as absolute what is relative. In this, as he knows, or ought to know, very well, he is doing violence to the fact. But this violence is harmless, provided he does not forget that what appears in abstract insulation in his formulæ exists in concrete and indissoluble union in Nature, and what he exhibits as unconditioned in thought is essentially conditioned in objective reality. The steps to all scientific knowledge consist in a series of representative fictions. When the old Greek sought to determine the properties of the circle, he began by constructing a polygon whose sides he subdivided until they were supposed to become infinitely small; and in his view every line of definite extent and form, i. e., every line which could become the subject of mathematical investigation, was composed of an infinite number of infinitely small straight lines. But he speedily found that, while this fiction enabled him to deduce a rule for calculating the area of the circle and otherwise to determine a number of its properties, nevertheless the circle and its rectilinear diameter were fundamentally incommensurable, and the quadrature of the circle was impossible. The modern analyst similarly determines the "locus" of a curve by the relation of small increments of coördinates arbitrarily established; but he is well aware that the curve itself has nothing to do with this arbitrary representation, and he very emphatically asserts the continuity of the curve by differentiating, or passing to the "limit" of, his increments—at the same time transforming his coördinates by changing their origin or their inclination, or even their system, from bilinears to polars, whenever he finds it convenient, with-

out ever dreaming that thereby he is in the least affecting the nature of the curve whose properties are under discussion. The astronomer, in calculating the attraction of a sphere upon a "material point," begins by assuming the atomic or molecular constitution of the attracting sphere, establishing a series of finite differences as one of the terms of his equation; but thereupon he takes the series to be infinite and the differences to be infinitely small, and very effectually dismantles the molecular scaffolding by integrating instead of effecting a summation of a series of finite differences. Observe: the astronomer begins with two fictions—the fiction of the "material point" (which is, in truth, a contradiction in terms), so as to insulate the attractive force and treat it as proceeding from the sphere alone, and the fiction of the finite differences representing the molecular constitution of the sphere; but the validity of his result depends upon the eventual rescission of these fictions and the rehabilitation of the fact. In like manner, the chemist represents the proportions of weight in which substances combine, as atoms of definite weight and figure, and the resulting compounds as definite groups of such atoms; and this mythical coinage has, no doubt, been serviceable in some ways. But, apart from the circumstance, avowed by thoughtful chemists themselves, that the symbols have become wholly inadequate to the proper representation of the facts, and that new representative fictions will have to be resorted to, it is important to bear in mind always that the symbol is not the fact, and that the fiction is very different from the reality. Newton derived many of the leading optical laws from his corpuscular theory of light and from the hypothesis of "fits of easy transmission and reflection." His theory for a time served a good purpose; but it proved, after all, to be but a convenient mode of symbolizing the phenomena with which he was familiar, and had to be discarded when the phenomenon of interference was observed. In 1824 Sady Carnot deduced the law of thermic action, which still bears his name, from an hypothesis respecting the nature of heat (supposed by him, as by nearly all the physicists of his time, to be imponderable matter), which is now known, or universally believed to be, erroneous. Since his time, Clausius, Rankine, Thomson, and Clerk Maxwell, have shown that thermic phenomena find a very convenient representation in the hypothesis that gaseous molecules are in a state of incessant motion; and Maxwell has even succeeded in predicting the phenomenon of the gradual cessation of the oscillatory movement of a disk, suspended between two other disks, in consequence of the friction of a gaseous medium, whatever be the degree of its tenuity, and this prediction has since been verified by experiment, just as Hamilton's prediction of conical refraction was verified by the experiments of Lloyd; but, of course, neither Clausius's and Rankine's formulæ, nor Maxwell's experiments, are conclusive as to the real nature of a gas. In all such cases science erects a scaffolding which is invariably kicked down as

soon as its work has been accomplished. And, if the scientific architects are so captivated with the scaffolding that they insist upon maintaining it intact, its eventual demolition is none the less sure in the progress of observation and experiment. Facts supply the *ictus calcis* which the theorist refuses to administer.

Du Bois-Reymond's proposition is nothing less than this, that natural science is constrained, by the law of all its methods, to exhibit the arbitrary scaffolding of the intellect as the real nature of the universe. He not only confounds the scaffolding of his intellect with its own structure, but he confounds this scaffolding with the structure of Nature. He mistakes the beams of his temporary platform for the rafters of the permanent edifice; the arbitrary masses of his mathematical calculations (the "atoms") for bricks of Nature's building; and the ropes of his scientific tackling (the "forces") for the ingenerate energy of the Universe. There are, it is true, passages in Du Bois-Reymond's lecture which may be construed as a virtual disclaimer of this, but his assumption that the limits of mathematical reasoning about atoms and their constant central forces are the irremovable bounds of all possible knowledge respecting physical phenomena, and the emphatic "*Ignoramus—Ignorabimus*," with which he concludes his lecture, utterly invalidate the disclaimer. He forgets that the framework on which he and his compeers have thus far been stationed is by no means the only scaffolding that can be devised. The spectroscope has convinced the chemist that a chemical analysis can be effected otherwise than by mixing substances in a testing-tube, and that he can react upon the gas of a distant comet as well as upon the hydrogen in the water which flows from a stop-cock in his laboratory. Modern analysis has shown that the limits of mathematical insight, which the synthetical geometrician supposed to be absolute, may be transcended indefinitely; and Gauss's and Hamilton's new conception which is now expanding into the calculus of operations, or calculus of quaternions, is opening theoretical vistas which, even to the analyst of modern times, seem next to illimitable. It is true that no mathematical wings will ever carry us into the regions of the "Absolute," and no spectroscopic vision will discern the indelible spectral bands of the "thing *per se*;" but, before we indulge in any lamentations over this fact, it may be well to examine the livery of the messenger who brings us the wonderful intelligence of the existence of these entities without all possible relation to the intellect, and to inquire of him how he became possessed of his message.

I must not be understood as asserting or intimating that our knowledge can ever be other than asymptotic to the endless and boundless fact of the universe. But there is a dogmatism of ignorance which is no less audacious than the dogmatism of sciolistic knowledge. The "*Ignoramus—Ignorabimus*" at the close of Du Bois-Reymond's lecture is at least as presumptuous as the pretended omnis-

cience of a giddy metaphysician. One of the urgent needs of modern physical science is a thorough investigation of the nature, methods, and aids of scientific cognition, and thus of the nature of its real limits, chiefly in the light of the teachings of comparative philology and comparative psychology. Max Müller has happily designated the tendency to "reify" intellectual concepts (or, as Mill expresses it in nominalist phrase, to mistake names for things), as "modern mythology." But this mythology is not at all confined to ordinary language; it extends to all the formularies, including those employed in scientific research, which serve as the intellectual net-work for the delineation of physical phenomena and for the exact mathematical determination of the laws of their interdependence.

The most pressing need of modern physical science, however, is the disengagement of the facts of observation and induction from their present theoretical complications. Most of the scientific theories of our day have their root in the metaphysics of three centuries ago, and some of the materialistic speculations based upon them are redolent of the ancient culture of the Middle Kingdom. Both in physics and in chemistry (not to speak of the biological sciences), the facts have long since transcended the narrow bounds of the prevailing scientific hypotheses, and have thus been either ignored or misinterpreted. On the remaining pages of this paper I desire to direct attention to some of the facts connected with the main subject of my present inquiry—the concept *force*.

Physical forces are distributed by modern science into two classes, *molecular* and *molar* forces. Molecular forces are those which determine the internal changes of a body, while molar forces cause the motion of the entire mass. Molecular forces, therefore, are the agencies which determine the particular state of the body in its physical relations, considering it as an independent whole—or, as it is termed in modern mechanics, as an independent conservative system—while the molar forces determine the physical relations of the body to other bodies which, together with it, are integrant parts of a greater whole, i. e., of a more comprehensive conservative system.

Modern science teaches that all physical forces, molar as well as molecular, are mutually convertible. This fact is discussed and illustrated in scientific treatises without number, and its importance is duly appreciated. But there is another fact connected with it, equally well known, the significance of which is not, I think, at all realized: all force in its physical origin is molecular. The power which grinds the wheat in the mill on the stream, or which drives the steam-engines in a factory; the force which propels the cannon-ball on its path of destruction, or the vital juices in a vegetable or animal organism in their course of vital regeneration; the energy which causes the muscles of a man's arm or the vessels of his circulatory system to expand and contract—all are alike of helio-planetary origin,

and are ultimately traceable to the "molecular" movements of the conservative system of which our planet is a part. It would be a work of supererogation to attempt to prove this, or to illustrate it in detail; it is sufficient to refer the reader to the eloquent exposition in Tyndall's "Heat as a Mode of Motion," p. 447, *et seq.* (Appletons' edition).

I need not say that I use the term "molecular force" simply because it is a generally-received term, and because I am constrained to use it in order to be intelligible, but that I do not intend to commit myself by this use to the theory of the constitution of matter which it implies. In like manner I use the term "force" with the reservation that it rightfully denotes, not a substantive entity distinct from matter, but the relation of at least two particular states of matter at a given moment.

The molecular character of molar motion is evinced in numerous ways, which are almost wholly neglected and ignored by the modern physicist. To take the simplest instance: when two solids impinge, so that an exchange or distribution of their motions takes place, they contract and immediately expand again, according to the degree of their elasticity. It is unnecessary to inquire whether or not a communication of motion between two absolutely rigid bodies is possible; all bodies, of which we know any thing, are more or less elastic, and therefore contract and expand at the instant of impact. And their contraction is accompanied by the evolution of heat, by the conversion of molar into molecular motion, while in the expansion we have a reconversion of molecular into molar motion. No transfer of molar motion ever takes place without this momentary transition through the molecular phase.

Since the establishment of the doctrine of the conservation of energy and the correlation and mutual convertibility of forces, physicists have repeatedly called attention to the fact that the old interpretation of the phenomenon of an apparent destruction of force is inaccurate, and that the true interpretation of this phenomenon consists in the tracing of the evanescent molar motion into resulting molecular motion. But they fail to observe that the old notions respecting the *transfer* of molar motion, when there is no loss, are in similar need of rectification.

Now, what is this molecular motion, in the light of the insight which, as I hope, has been gained in the foregoing discussion? Simply an exhibition of the struggle involved in the formation or constitution of a body as a distinct conservative system. All molecular energy is in its nature constitutive, formative, or structural. All kinetic energy, or actual motion, represents the progress of morphological action in periodical alternations of advancing and retrograde metamorphosis. And the main problem of physical science is, not to calculate the play of atomic motions, under the sway of their constant

central forces, but to trace the differentiation and transformation of material forms as determined by the differentiation and transformation of the formative energy of the universe. In this connection, observation and experiment have brought to light a number of the most significant facts, to one of which I may be permitted to draw attention before the conclusion of this paper. Force, or, more correctly speaking, energy, is not only indestructible, like mass; it not only passes through a cycle of transformations corresponding to the metamorphic round of physical forms; it is not only specialized at even pace with the specialization of its corresponding material structures; but, just as the progressive specialization of these material structures is, on the whole, an advance in the direction of greater definiteness and more perfect concretion (in the case of inorganic bodies, generally accompanied by greater condensation): so, also, the specialization of formative energy is, on the whole, characterized by an ever-increasing intensification. Generally speaking, the more advanced the stage of material concretion, the greater the intensity of its constitutive force. Faraday has somewhere observed that the chemical force contained in a drop of water, if transformed into heat and light, would be sufficient to illuminate the heavens. Of course, this intensification of force, in proportion to the condensation, concretion, and differentiation of the forms produced by it, is not a thickening of a substantive entity, but is simply an increasing complication in the relations in the establishment of which all realization consists. The energy which forms and maintains the higher and more definite forms of material existence has to overcome and to hold its own against not only the inherent energy of the primary physical form, but against the specialized energy of the intermediate forms as well.

I ought, perhaps, to observe here that, whenever energy is seemingly destructive, it is in reality reconstitutive of a conservative system of a lower grade.

But I must not be led into discussions which belong to special science, and are in strictness foreign to my theme; and, so far as I am at liberty to enter upon these discussions, especially in the field of chemical science, they must be reserved for another article.

SKETCH OF DR. J. W. DRAPER.

THE period from 1830 to 1870 is very strikingly marked in the history of science. It opens with great discoveries in electricity, and closes with very brilliant ones in light. Its middle portion is illustrated by the application of chemistry to physiology, which led to a revolution in the latter science, and indeed changed the face of

medicine. It is adorned with many great inventions, such as photography, the electric telegraph, the construction of railways, and ocean steam navigation. The great wars it has witnessed, the Franco-Italian, the Crimean, the Prusso-Austrian, the Prusso-French, and the American Civil War, have occasioned, as all great wars inevitably do, much intellectual activity and profound social changes. Among the latter are the emancipation of the vast serf population of Russia, and of four million slaves in America. But, perhaps, most important of all—partly through the increase and diffusion of knowledge, partly through more rapid and incessant national intercommunication—ideas liberal in politics and elevated in religion have asserted their sway.

The generation that lived in this period has therefore fairly performed its share in the promotion of modern civilization. There is no European nation which has not participated in this great movement—none that cannot offer a list of the names of its people who may lay claim to a part of the honor of the success. In this respect America is not behind others—she too has done her share, both as regards science and industrial inventions. Among those of her citizens who have devoted their lives to these objects, and who by their successful pursuit have done honor to the country, and won for themselves an eminent name in the world of science, is the subject of our present sketch, JOHN WILLIAM DRAPER.

He was born at St. Helen's, near Liverpool, in 1811, and received his education for the most part from private instructors. At eleven years of age he was sent to one of the public schools of the Wesleyan Methodists, of which denomination his father was a minister. He remained there, however, only two years, and was then returned to private instruction. When the University of London was opened, he was sent there to study chemistry under Dr. Turner, at that time the most celebrated of English chemists. At the instance of several of his American relatives, he came to America, and completed his medical education at the University of Pennsylvania, graduating in 1836 with so much distinction that his inaugural thesis received the unusual compliment of being published by the faculty of that university. Shortly afterward he was appointed Professor of Chemistry in Hampden Sidney College, Virginia, and in 1839 received an appointment to the same professorship in the University of New York, with which institution he has ever since been connected.

Dr. Draper's earliest scientific publications were on the chemical action of light, a subject at that time almost completely neglected. Eventually he published in American and foreign journals, or read before scientific societies, nearly forty memoirs in relation to it. It would be impossible in this short sketch to give an enumeration of the facts contained in these papers. We shall, therefore, select only a few of the more prominent ones for remark.

Of all the chemical actions of light, by far the most important

is that of the decomposition of carbonic acid by the leaves of plants, under the influence of sunshine. On this the whole vegetable world depends for its growth, and the whole animal world, directly or indirectly, for its food. The decomposition in question is essentially a deoxidation, and up to about 1840 it was generally supposed to be due to the violet rays of the spectrum, which, in accordance with the views held at that time, were regarded as producing deoxidizing actions, and were consequently known as deoxidizing rays. But this was altogether an assumption unsupported by experimental proof. Prof. Draper saw that there was but one method for the absolute solution of the problem, and that was by causing the decomposition to take place in the spectrum itself. In this delicate and beautiful experiment he succeeded, and found that the decomposition was brought about by the yellow rays, at a maximum by those in the vicinity of the Fraunhofer fixed line D, and that the violet rays might be considered as altogether inoperative. The memoir containing this result was first read before the American Philosophical Society, in Philadelphia, and immediately republished in London, Paris, and Berlin. It excited general interest among chemists. Even up to the present year it has furnished to the German experimenters the basis of a very interesting discussion in photo-chemistry.

In 1842 Dr. Draper discovered that not only might the Fraunhofer fixed lines in the spectrum be photographed, but that there exists a vast number of others beyond the violet, which up to that time had been unknown. He also found three great lines less refrangible than the red, in a region altogether invisible to the eye. Of these new lines, which more than doubled in number those of Fraunhofer, he published engravings. He also invented an instrument for measuring the chemical force of light—the chlor-hydrogen photometer. This was subsequently extensively used by Bunsen and Roscoe in their photo-chemical researches. In their paper, read before the Royal Society, in 1856, they say, "With this instrument Draper succeeded in establishing experimentally some of the most important relations of the chemical action of light."

Most of the papers he had written up to 1844 were in that year collected and published together, in a book bearing the title of a treatise on "the Forces producing the Organization of Plants." In this there are a great many experiments on capillary attraction, the flow of sap, endosmosis, the influence of yellow light on plants, etc.

His memoir "On the Production of Light by Heat," published in 1847, was an important contribution to spectrum analysis; among other things it gave the means for determining the solid or gaseous condition of the sun, the stars, and the nebulæ. In this paper he established experimentally that all solid substances, and probably liquids, become incandescent at the same temperature; that the thermometric point at which such substances are red-hot is about 977° Fahr.; that the

spectrum of an incandescent solid is continuous, it contains neither bright nor dark fixed lines; that from common temperatures up to 977° Fahr. the rays emitted by a solid are invisible, but at that temperature they impress the eye with the sensation of red; that the heat of the incandescing body being made continuously to rise, other rays are added, increasing in refrangibility as the temperature ascends; and that, while the addition of rays so much the more refrangible as the temperature is higher is taking place, there is an augmentation in the intensity of those already existing.

This memoir was published in both American and European journals. An analysis of it was read in Italian before the Royal Academy at Naples, July, 1847, by Melloni, which was also translated into French and English.

But, thirteen years subsequently, M. Kirchhoff published, in a very celebrated memoir, considered by many as the origin of spectrum analysis, and of which an English translation may be found in the *London and Edinburgh Philosophical Magazine*, July, 1860, the same facts under the guise of mathematical deductions, with so meagre a reference to what Draper had done that he secured the entire credit of these discoveries. In an historical sketch of spectrum analysis subsequently published, Kirchhoff avoided all mention of his American predecessor.

Dr. Draper was the first person who succeeded in taking portraits of the human face by photography. This was in 1839. He published a minute account of the process at a time when in Europe it was regarded as altogether impracticable. He also was the first to take photographs of the moon, and presented specimens of them to the New York Lyceum of Natural History, in 1840.

In 1841 the University of New York established its medical college, Dr. Draper being appointed Professor of Chemistry in it. A very great change in medical studies and teaching was at that time impending. The application of chemistry to physiology was about to be made by Liebig and his school. In these new views Dr. Draper completely coincided, and therefore soon afterward physiology was added to his chair. He now resumed his early chemico-physiological researches, and eventually published the result of them in "A Treatise on Human Physiology, Statical and Dynamical." This work at once became a standard text-book in American colleges. It has passed through a great many editions, and was translated into several foreign languages. The Russian edition is used in the higher schools of that country.

It is impossible in our limited space to give an adequate account of the new facts and the important views, founded on extensive and expensive series of experiments, contained in this work. Among them, however, we may mention, an explanation of the selecting action of membranes; electrical theory of capillary attraction; cause

of the coagulation of the blood; theory of the circulation of the blood; explanation of the flow of sap in plants; endosmosis of gases through thin films; measure of the force of endosmosis; respiration of fishes; action of organic muscle-fibre of the lungs; allotropism of living systems; new facts respecting the action of the skin; functions of nerve-vesicles and their electrical analogues; function of the sympathetic nerve; explanation of the action of certain parts of the auditory apparatus, particularly the cochlea and semicircular canals; new facts respecting the theory of vision and theory of muscular contraction. The special object of the book was, to apply physical theories in the explanation of physiological facts, to the exclusion of the so-called vital principle of the old physicians.

Dr. Draper is a man of a philosophical cast of mind, by which he was drawn to the study of phenomena in their more comprehensive aspects and relations. The wide range of his scientific acquirements, and especially his mastery of physiology, formed an admirable preparation for studying the subjects of human development and the course of civilization from a scientific point of view. His "Physiology" was accordingly soon followed by a work of which the intention was to show that societies of men advance under the government of law. This was entitled "A History of the Intellectual Development of Europe." Few philosophical works have attained so quickly to celebrity. Many editions of it have been published in this country, and it has been translated into almost every European language. The *Westminster Review*, speaking of it says: "It is one of the not least remarkable achievements in the progress of positive philosophy that have yet been made in the English tongue. A noble and even magnificent attempt to frame an induction from all the recorded phenomena of European, Asiatic, and North African history."

Though in his earlier years Dr. Draper was a skillful mathematical analyst, he has published but few mathematical papers, the most important being an investigation of the electrical conducting power of wires. This was undertaken at the request of Prof. Morse, at the time he was inventing his telegraph. The use made by Morse of this investigation is related by him in *Silliman's American Journal of Science and Arts*, December, 1843. The paper shows that an electrical current may be transmitted through a wire, no matter what the length may be, and that, generally, the conducting effect of wires may be represented by a logarithmic curve. Among electrical memoirs there is one on the tidal motions exhibited by liquid conductors, and one on the electro-motive power of heat, explaining the construction of some new and improved forms of thermo-electric batteries. An abstract of these improvements is given in the last edition of the "Encyclopædia Britannica" (Art. Voltaic Electricity).

Dr. Draper was the first person to obtain photographs of the diffraction spectrum given by a grating, and to show the singular advan-

tages which that spectrum possesses over the prismatic investigations on radiations. In a memoir on the production of light by chemical action (1848), he gave the spectrum analyses of many different flames, and devised the arrangement of charts of their fixed lines in the manner now universally adopted. A memoir on phosphorescence contains the experimental determination of many important facts in relation to that property. Among purely chemical topics he has furnished a method for the qualitative determination of urea by nitrous acid.

In 1864, at the request of the New York Historical Society, Dr. Draper gave four lectures before that body, which were subsequently published under the title of "Thoughts on the Civil Policy of America." They were respectively on the influence of climate upon man; on the effects of emigration; on the political force of ideas; and on the natural course of national development. They contain discussions of several interesting points, which since that time have largely occupied public attention, such as the internal emigration from the Atlantic States to the West, the Asiatic emigration to the Pacific States, the political effects of polygamy in Utah, the tendency of democratic institutions to centralization, a comparison of the European with the American method of government.

No account of Dr. Draper's labor and influence for the promotion of science would be complete that did not mention the admirable series of Introductory Lectures with which he opened his chemical courses in New York from 1840 to 1850. Clear in statement, fresh and striking in their views, and lively, poetic, and witty, as well as instructive, they were well fitted to awaken the enthusiasm of students. Those on "Oxygen," "Atmospheric Air," "Water," and "Phosphorus," were especially brilliant. We have repeatedly tried to induce their author to have them collected and reprinted, but he says they were only fragments designed for a transient purpose, and are not worth preserving in a permanent form. Dr. Draper's manner as a lecturer is quiet and deliberate—too subdued and equal for stirring effect, but perfect for exposition. As a speaker, he has been rarely drawn out of the collegiate sphere, but such efforts as his Introductory Lectures and his felicitous address at the Tyndall banquet show that he has the elements of humor and an art of putting things that would have given him success in the popular field if he had cared to seek it.

From 1860 to 1870 Dr. Draper did but little in scientific research, devoting himself mostly to historical works. During this time he published his "History of the American Civil War," in three volumes. His opportunities for giving accuracy to this work were very great. Mr. Stanton, the Secretary of War, issued orders to the Adjutant-General of the Army of the United States to "furnish him with copies of all orders, reports, correspondence, telegraphic dispatches, or other documents on file in the War Department, as he might request, and to permit him to inspect and have copies of any maps, plans, and other pa-

pers necessary for the preparation of his work, and to furnish him with statistical information respecting the armies of the United States, their organization, and operations." This order included all the Confederate archives in possession of the War Department. Nor was the interest of the Secretary of War limited to this: he supplied also a large amount of personal information of the utmost value. Access was not unfrequently given him to documents and correspondence of the most confidential kind, with a view of guiding him to correct conclusions, and many of the most decisive military operations are detailed from private memoranda furnished by the commanding officers themselves. As was the case with Dr. Draper's other works, this also has been largely republished in Europe.

In the summer of 1870 Dr. Draper suffered a severe bereavement in the loss of his wife. Of Brazilian birth, she was connected with an ancient and noble Portuguese family. She had rendered his domestic life a course of unbroken happiness, and doubtless she was the exemplar before his eyes when he wrote that often-quoted passage in his "Physiology," in which, after depicting the physical and intellectual peculiarities of woman, he says: "But it is in the family and social relations that her beautiful qualities shine forth. At the close of a long life checkered with pleasures and misfortunes, how often does the aged man with emotion confess that, though all the ephemeral acquaintances and attachments of his career have ended in disappointment and alienation, the wife of his youth is still his friend. In a world from which every thing else seems to be passing away, her affection alone is unchanged, true to him in sickness as in health, in adversity as in prosperity, true to the hour of death."

Of their six children, one died in infancy; the survivors are three sons and two daughters. Of the former, the eldest is Professor of Natural History in the College of the City of New York; the second, Professor of Physiology in the University of New York; the third, Director of the Meteorological Observatory in the New York Central Park.

After the death of his wife, Dr. Draper spent the following winter in Europe, chiefly in Rome. Since his return he has published two short memoirs: one, on the "Distribution of Heat in the Spectrum," showing that the predominance of heat in the less refrangible regions is due to the action of the prism, and would not be observed in a normal spectrum, such as is formed by a grating; and that all the rays of light have intrinsically equal heating power. The second is an investigation of the distribution of chemical force in the spectrum. All these scientific researches, to which so many years of his life have been devoted, have been at his own expense; he has never received any extraneous aid, though many of them have been very costly. He has never taken out any patent, but has given the fruits of his investigations and inventions freely to the public.

EDITOR'S TABLE.

MILL, EDUCATION, AND SCIENCE.

THE first part of Mr. Mill's autobiography gives an instructive account of his early education. He had before propounded his general views upon this subject in a celebrated address delivered at the University of St. Andrew's in 1867. Mr. Mill had won the enviable distinction of possessing "the most elaborated mind in Europe," and this, together with the confessed ability of his argument, gave it wide influence with the public. But there were many who thought that Mr. Mill, on that occasion, reasoned too much from his own exceptional experience, and that, as an argument addressed to the times, the performance was misleading and injurious. The record of Mr. Mill's mental history, now published, throws important light upon the view promulgated at St. Andrew's, and, as the question involved is of great practical importance, the present is a fitting occasion to offer some remark upon it.

There has grown up a grave conflict between ancient learning and modern science as means of educating the human mind. It originated in the rise of a new order of knowledge derived from the extensive study of Nature in recent times. The old system was, however, strongly intrenched in the field of education; it was interwoven with the world's literature, and all its venerated traditions; it appealed to the generations of the great that it had trained, and it was in possession of the old institutions of learning, fortified by rich endowments, and backed by state and church. But, as modern knowledge has grown in extent and influence, and institutions have been liberalized, and the idea of general education has become a part of civilization, there has been a growing demand for the right of science to have a more decisive voice in education, and this demand has been partially yielded to by the modification of old methods and the establishment of new. Such changes have only resulted from long and earnest conflict between opposing views, and, whatever may be the merits of this controversy, one thing would seem to be certain, that it has been a natural and inevitable outgrowth of the progress of events.

At the outset of his address, Mr. Mill recognized this struggle as "the great controversy of the present day, with regard to the higher education, the difference which most broadly divides educational reformers; the vexed question between the ancient languages and the modern sciences and arts." But, from Mr. Mill's point of view, the antagonism is unreal, and the controversy futile and groundless. Between the two systems of culture he acknowledged no rivalship, but said, "Why not both?" To the obvious answer that average students have neither capacity nor time for such extensive mental conquests, he indignantly replied: "I am amazed at the limited conception which many educational reformers have formed to themselves of a human being's power of acquisition." Mr. Mill, accordingly, proceeded to outline a system of study more consonant, as he thought, with the powers and possibilities of the human mind. The limitations of capacity assigned by experience and embodied in practical plans of education he gave to the winds, and offered an ideal of scholarship and a range of acquisition of most majestic proportions. But it was so grandly

his own, and so out of all relation to the hard workaday facts of college and university life, that it practically served little other purpose than to confirm a bad state of things, and to put a new weapon into the hands of the educational obstructives. Let us see how this result was effected.

Mr. Mill began by enforcing the largest claims of ancient learning. He outstripped all contemporaries in the extent and rigor of his classical exactions. He refused a place to modern languages in the collegiate course, saying that these can be best studied in the countries where they are spoken, while three or four of them can be easily picked up after the classical tongues have been secured. With the modern languages modern literature was also ruled out. "The only languages, then, and the only literature," says he, "to which I would allow a place in the ordinary curriculum are those of the Greeks and Romans, and to these I would preserve the position in it which they at present occupy." The reasons which he offered for studying Greek and Latin were far from being the stock-reasons that we are accustomed to hear. These languages are to be acquired for the purpose of mastering their literary contents. Not for any such slight considerations as the bearings of the classical languages upon English, or to be able to understand current quotations, or for the mere discipline of lingual study, are they to be acquired, but that the student may enter into the spirit and breathe the atmosphere of ancient life. He is to be at home in Greek and Roman thought as he is in that of his native speech. "We must be able in a certain degree to think in Greek if we would represent to ourselves how a Greek thought; and this not only in the abstruse region of metaphysics, but about the political, religious, and even domestic concerns of life." Translations are not to be accepted. Though the profoundest scholar, after life-long preparation, renders an ancient author into English, the student of the "ordinary curriculum" must be able to translate it better for himself. He must not trust to other person's impressions, but must have every thing at first hand, and go directly to the fountain-head. Greek and Latin must be studied, that the student may get at the original materials of history, so as to check and correct the historians. The modern classics, English, German, and French, are insufficient as models; those of Greece and Rome are more perfect, and therefore the student must use them to form his style and perfect his literary taste.

Mr. Mill then went on to argue the claims of the sciences, but his work was superfluous. Methuselah might have listened to him with interest, but practical men knew that the demands he had already made were far beyond the possibilities of realization by general students in the usual period of study. Already he had laid out a scheme of professional scholarship not attainable in its completeness by one in a hundred of those who give their lives to it. Mr. Mill's words, to be sure, were hot with scorn when he referred to the "shameful inefficiency," and "wretched methods," and "laborious idleness," of current classical teaching—the constant fruits of the system for centuries, as testified to by similar denunciations of the most eminent men. But he did not say, "Improve these methods or get them out of the way." On the contrary, he indorsed unqualifiedly Greek and Latin studies in "the position which they at present occupy;" and, to carry out his views, nothing remained but to give them a greatly-increased attention. The practical effect of his argument was, to lend renewed and powerful support to the classical system as it now exists, and this was the general interpretation given to the address. It was universally hailed as a triumph of the classical party, and thrown in

the face of the friends of scientific education as a final refutation of their case. It was a victory of the classicists simply because it gave them every thing they asked. If they could have classical studies assured on such a scale as Mr. Mill proposed, there was no longer any fear of scientific encroachment. Already in possession of the appliances of education in existing institutions, if his programme is accepted, they will always remain in possession. Mr. Mill said, "Why not both?" But his argument was a practical surrender to one side, because, on his scale of study there is not time for both, and the party that comes first gets all.

The question now arises, Was this exalted estimate of classical studies the result of an impartial survey of the field of knowledge and an equal appreciation of science, or of an overwhelming bias produced by a one-sided training, of which Mr. Mill had been the victim in his youth? The Autobiography here comes to our assistance, and we learn from it the following extraordinary facts:

Mr. Mill's father was a man of great intellectual vigor, and a disciplined scholar, and he determined to make his son an example of the most thorough and perfect form of education. Critical, vigilant, and exacting, he took entire charge of the boy's studies. Fortunately, the lad had great native capacity, and a fine, tenacious organization, and his proficiency equaled his father's efforts and expectations. At three years old he commenced the study of Greek, and only faintly remembers going through Esop's "Fables" in that language. He then read the "Anabasis," and, before he was eight years old, he had read all the nine books of Herodotus, the first six "Dialogues" of Plato, all Xenophon's "Cyropædia," the "Memorabilia" of Socrates, and portions of Diogenes Laertius, Lucian, and Isocrates. During this time he also learned arithmetic, and read the histories of Robertson, Hume, Gibbon, Watson, Hooke, Rollin, Burnet, Langhorne's Plutarch, Millar's "Historical View of the English Government," Mosheim's Ecclesiastical History, and various other ponderous books; nor were these merely cursory or desultory readings. His father required every day a full account of what he had read. Notes, abridgments, and synoptical statements, had to be made, and in their daily walks the father enforced the lessons, and gave him explanations and ideas on various questions of civilization, government, mental philosophy, and morality; and all this the son was required afterward to reproduce in his own words.

Amazing as was the work done up to his eighth year, it increased, in a most oppressive ratio, in the next four years. English and Greek being not sufficient, he now went into Latin, and, as he acquired it, taught it to his brothers and sisters. Between his eighth and twelfth year, he read Virgil, Horace, part of Livy, the whole of Sallust, parts of Ovid, Terence, Lucretius, Cicero, the "Iliad" and "Odyssey," one or two Greek plays, the whole of Thucydides, Aristotle's "Rhetoric," Tacitus, Juvenal, Quintilian, and the principal "Dialogues" of Plato. From ten to eleven he wrote a "History of Rome" that would have filled an octavo volume. He also learned elementary geometry, algebra, the differential calculus, and other parts of the higher mathematics. Logic, and the "Organon" of Aristotle, had not been neglected; and, at thirteen, he corrected the proof-sheets of his father's "History of India," and went through with him a complete course of political economy, being required to correct "the more superficial views of Adam Smith by the superior lights of Ricardo." Of course, the boy was kept to the inexorable drill, upon subjects selected by his father; but, in his spontaneous reading,

he says that his strongest predilection was ancient history. "A book which, in spite of what is called the dryness of its style, I took great pleasure in, was the 'Ancient Universal History,' through the incessant reading of which, I had my head full of historical details concerning the obscurest ancient people; while, about modern history, except detached passages, such as the 'Dutch War of Independence,' I knew and cared comparatively little."

And so young Mill became a prodigy of Greek, Latin, and antiquated learning. The dead languages and their contents were fairly burned into his organization. On his classical acquisitions were superinduced history, mathematics, metaphysics, and political ideas—studies which he might have pursued if he had been the son of Plato instead of James Mill. But of the sciences of Nature there was nothing gained worth the name. At the mental stage in which all the foregoing acquirements had been made he had received not the slightest scientific instruction, and had only read a little in experimental books by way of amusement. He says: "During this part of my childhood, one of my greatest amusements was experimental science, in the theoretical, however, not the practical sense of the word; not trying experiments—a kind of discipline which I have often regretted—nor even seeing but merely reading about them." Mr. Mill subsequently paid more attention to science by reading; he heard lectures on zoology and chemistry, and did something with botany as an observer and collector. But of science in the educational sense of the classics, as an agency to mould the mind by its special discipline, he was utterly destitute. He neither pursued it in its objects, nor mastered it in its principles, nor cultivated the habit of original and independent research. The whole spirit of his education, indeed, was different; it was for polemics rather than for discovery. The intellectual exercise in which he says he was most perseveringly exercised by his father was the old scholastic logic, which he thinks is "peculliarly adapted to an early stage in the education of philosophical students, since it does not presuppose the slow process of acquiring by experience and reflection valuable thoughts of their own." His training was fitted to make him shine in debating societies, of which he was a frequenter, and he organized one at the age of sixteen. And such was his proficiency that, it was said, "a university man, loaded with honors and preceded by a blazing reputation, having been induced, in an evil hour, to take the chair at a discussion, crumbled to dust in the presence of our Titan, and passed out of count utterly."

The effect of neglect of science in Mr. Mill's education is seen in his remarkable judgment of himself. In his Autobiography he makes the astounding statement that in "natural gifts I am rather below than above par; what I could do could assuredly be done by any boy or girl of average capacity," and he assumes to have had the start of his contemporaries for a quarter of a century, simply from the mode in which he was instructed. Mind is thus dealt with as if it were a disembodied agency capable of being manipulated into any state; while organic conditions and limitations, and the influence of heredity, are discredited at a stroke. No allowance is made for the fact that he derived his fine organization from a father of great intellectual capacity; yet, nothing is better established by science than that traits of character are transmissible, and that this circumstance bears powerfully upon the problem of human educability. Physiologists well know that the children of cultivated parents not only inherit superior mental aptitudes and capacities, but that they have greater power of psychical endurance, and can

stand far greater mental exertion without injury, than the children of uncultivated parentage. Such a discipline as young Mill underwent would have reduced most children to idiocy, or killed them outright. Mr. Mill was an eminent student of mind, but it is very clear that he dealt with it from the ancient point of view, and knew very little of or cared very little for what modern science has had to say about it.

And even he, with his tough and vigorous organization, barely escaped the consequences of such gross error reduced to practice. At twenty he passed into a cloud of gloom and despondency. He became indifferent to his pursuits, sleep brought no relief, and he had thoughts of suicide. He became painfully anxious, under the notion that, if all he had been striving to attain could be realized, there would be nothing left to live for. Brain-disturbance from overtasking was evinced by delusion, like that of Martyn, who, when he had come out Senior Wrangler, was taken with the crazy fancy that mathematics were an invention of Satan, and that he had been led into a net of destruction. Mr. Mill had evidently reached the verge of a cerebral break-down, when he changed the course of his mental action by going into emotional literature, and ascribed his escape to Wordsworth's poetry. Had he been as deep in physiology as he was in Greek, and made use of his knowledge, this dangerous state might not only have been better interpreted, but probably quite avoided.

When, therefore, Mr. Mill, some fifty years later, in chalking out a system of education for the students of St. Andrew's, said of ancient and modern knowledge, "Why not both?" he was himself a living refutation of its possibility. He had worked himself up to the very breaking-point in the enormous accumulation of classical and other acquisitions, while modern thought had not been correspondingly mastered. The law of mental limitations, by which one thing can only be had at the expense of another, was in as full force in his case as in that of inferior minds; and his classical surcharging involved a correlative deficiency in science which has unquestionably been an element of weakness in his own career. We do not deny that Mr. Mill had a very considerable acquaintance with science, and only insist that it was neither up to his own standard of thoroughness in other departments, nor was it sufficient for his own requirements as a thinker ambitious of controlling the mind of his age. His book on "Logic," undoubtedly a great work, would have been a greater if a part of the effort spent upon classical history had been given to the history of science. But, while demanding that students shall learn dead languages, to get at the originals of political history, he was content, or rather he was compelled, to take scientific history at second-hand.

Such was the deficiency of the work in this respect that, although, as Mr. Mill states in the Autobiography, Prof. Bain "went carefully through the manuscript before it was sent to press, and enriched it with a great number of additional examples and illustrations from science," yet it was exposed to the telling criticisms of Dr. Whewell, the eminent historian of science, for the faulty and ill-chosen character of the instances of discovery selected to exemplify and confirm his methods.

Mr. Mill was at the head of a school of thinkers which maintained what is called the Experiential Psychology; that is, in Mr. Mill's language, "there is not any idea, feeling, or power, in the human mind, which, in order to account for it, requires that its origin should be referred to any other source than experience." The problem of mind, as thus conceived, is one of the grandest openings of modern thought. Be the doctrine true or false, it brings

the study of mental phenomena into more close and vital relations with the surrounding universe than had been possible with the older metaphysical views. James Mill was the author of the ablest exposition of this doctrine that had yet appeared; and his son, therefore, through his father's early and able teaching, had the rarest advantages for pursuing the inquiry and occupying the field. But another and a younger man came into that field, and took possession of it. At the age of thirty-five, Mr. Herbert Spencer published his "Principles of Psychology," of which Mr. Mill himself says, "it is one of the finest examples we possess of the psychological method in its full power." Subsequent criticism has strengthened this judgment, and assigned to that work an unrivaled position in the original psychological literature of its time. Mr. J. S. Mill's greatest work upon mind is undoubtedly his polemical criticism of Sir William Hamilton; but, after this was published, and the works of Spencer and Mill were left to their influence upon the British public, Prof. Masson, in a lecture before the Royal Institution, gave expression to the growing conviction concerning Spencer, that, "if any individual influence is visibly encroaching on Mill's in this country, it is his."

What, now, was the secret by which Mr. Spencer was enabled to beat Mr. Mill in the field where he was most at home, and had every apparent advantage? It was simply the difference in the education of the two men. Both were examples of great native power of mind; both were educated by their fathers, and neither went to the universities. But while Mill was sent back in childhood to the world of two thousand years ago, and spent his force in learning half a dozen languages, and in loading himself down with the erudition of antiquity, Mr. Spencer was content with his English, left antiquity to itself, and entered in childhood into the sphere of modern thought. Mr. Mill had spent his energies on his splendid scholastic preparation, and could give only the remnant of his powers to the profounder intellectual movement of his own time. Mr. Spencer broke freshly into the study of Nature and science, unperverted by ancient ideas, and unincumbered by antiquated learning, and was thus enabled to make those extensive modern acquisitions by which he has attained such power over the thought of his own time. While Mr. Mill was drilling with the school-logic, which calls for no original thought, Mr. Spencer was making discoveries in experimental science, and forming his own opinions on the basis of the most recent knowledge; and while, in the study of mind, Mr. Mill sunk into little better than a mere commentator on his father's ideas, Mr. Spencer took up the great question from his own independent point of view, and has given his contemporaries, perhaps, the most original contribution of the century to the science of mind. Wherever the two men are brought into comparison, the enormous advantage of Spencer, through his mastery of scientific thought, is confessedly apparent. Mr. Mill wrote a formal work upon the woman question, as he might have written it two thousand years ago, and as if science had contributed nothing that is valuable in its elucidation: Mr. Spencer has lately crossed the field, treating the psychology of the sexes incidentally, and, as a contemporary remarks, his brief sketch makes the "Subjection of Woman" appear "obsolete and antediluvian" in comparison with it.

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LITERARY NOTICES.

REPORT OF THE GEOLOGICAL SURVEY OF OHIO. Vol. I., GEOLOGY AND PALEONTOLOGY. Part I., GEOLOGY; Part II., PALEONTOLOGY. Published by authority of the Legislature of Ohio. Columbus, 1873.

THESE two octavo volumes, which together form the first volume of the final report on the survey of Ohio, mark an important advance in the scientific knowledge of the character, history, and resources of our country. Since the survey was undertaken in 1869, three preliminary reports have appeared, giving the progress of discovery and labor for each year, and containing much valuable and interesting information. But here we have the beginning of the end, the first installment of a series which is to comprise some six volumes, and which will be a model in many respects for similar works in years to come.

As long ago as 1836 an attempt was made to have a geological survey in Ohio, and two annual reports of progress were published under the direction of Prof. W. W. Mather and Dr. S. P. Hildreth, together with several other gentlemen since eminent in geological study. The panic of 1837, however, caused the abandonment of the work by the Legislature, a mistaken economy which much retarded and impaired the development of the resources of the State. It was not until 1869 that the enterprise was resumed, and placed in the hands of the very able corps of gentlemen who have so well performed their work.

At the head of the survey was placed Dr. John S. Newberry, whose ability has found full scope, and whose reputation has gathered new laurels in this honorable service to his own State. Associated with him are gentlemen of high standing and capacity, Profs. E. B. Andrews, Edward Orton, and J. H. Klippart, as assistant geologists, and Dr. T. G. Wormly as chemist; while the work of paleontology has been divided between Dr. Newberry and Prof. F. B. Meek, so well and widely known in this especial department.

The second volume, soon to appear, will be composed, like the first, of two separate parts, on geology and paleontology; the third volume will treat of the economic geology of Ohio; and the fourth, of its agriculture, botany, and zoology. Part I. of the first volume has some of the mechanical defects that generally appear in public documents issued by State printers; but Part II. is a fine specimen of a book. A very large edition was voted by the Legislature, for the purpose of making the work familiar to the people of the State; and Dr. Newberry has been most successful in his endeavor to render the subjects treated of plain to all intelligent readers, so that these reports may be not only a treasure-house for students of science, but a means of information and instruction for the people at large.

The first part, on geology simply, forms an octavo of 680 pages. It opens with some general discussions, which properly introduce such a volume, and then passes on to the local details by counties. To any but specialists in geology, the general chapters in the First Section will possess the chief amount of interest; but there are doubtless many professional students of the science who could derive great benefit from these unpretending but masterly pages. After a brief sketch of the history of the survey, Dr. Newberry gives four chapters treating respectively of the physical geography of Ohio, of its geological relations to the rest of the country, and of its geological structure through the Silurian and Devonian formations.

Those who are acquainted with Dr. Newberry's cast of mind and method of treatment, will recognize these chapters as eminently characteristic, in the wide range and striking power of their generalizations, and the clearness of statement which pervades them. The second chapter, on the Physical Geography of Ohio, is in reality a brief but admirable summary of the physical geography of North America. Its discussion of the important question of the relation of forests to rainfall should be read by every intelligent man. With few exceptions, all students of science are agreed as to the destructive effects produced upon climate by the removal of woods from a country. This lesson cannot be too soon or too earnestly pressed upon the attention of our people and our

governments, both State and national. It has been held by some that the removal of forests causes an actual lessening of the annual rainfall; but this view is hardly borne out by recorded observations. The same injury, however, is equally accomplished in a somewhat different way. The removal of timber lays the ground open to rapid evaporation, and, worse still, causes the surface covering of earth, mould, etc., to be washed away from the unprotected sides of hills and mountains. The consequence is that the same yearly amount of moisture, instead of being slowly and gradually discharged by the brooks and streams, rushes away in destructive torrents and freshets, such as are all too familiar every spring, when the winter's snow is melting. The water-supply being thus lost all at once, the steady streams and rivers of a generation or two past dwindle in the summer to fitful and worthless rills. Such is the harvest of disaster from "our great lumbering interest."

Chapter III., on the "Geological Relations of Ohio," is yet more interesting in a purely scientific aspect. It begins with a brief outline of the characteristic features of the several great periods of geological history, as represented by the deposits in North America. Here Dr. Newberry gives, in a popular form, the gist of his discussion lately presented to the American Association of Science at Portland, and more recently to the National Academy of Arts and Sciences, at its session in this city in October last, on "Cycles of Deposition in Sedimentary Rocks," a generalization unsurpassed for its beauty, its simplicity, its wide-reaching grasp, and its lucid explanation of a multitude of details, previously insignificant and often wearisome.

Each of the great ages of palæozoic geology—the two Silurians, the Devonian, and the Carboniferous—represents, in this view, a grand invasion of the sea upon the land, slowly spreading itself over the continent, mainly from the west and south, and laying down a series of sediments in a fixed and regular order, depending on the increasing depth of the advancing waters. No one, it would seem, can look at the facts in a broad and philosophical view, excluding of course the thousand details which cause partial modifications in every such great operation of Nature, without recognizing here a new light cast upon the hitherto unmeaning succession of varying kinds of deposits.

The remainder of this volume is occupied with the detailed description of the geology of twenty-one counties—nearly one-fourth of the State—by Profs. Andrews and Orton, Dr. Newberry, and Messrs. M. C. Read, G. K. Gilbert, and N. H. Winchell, assistants. While all these accounts are full of valuable matter, especial interest attaches to Prof. Orton's excellent account of the lower Silurian formation, known in Ohio as the Cincinnati Group, and to Mr. Gilbert's summary of the surface geology of the Maumee Valley, which is rich in remarkable illustrations of the effects of the great sheet of ice, and afterward of the broad expanse of water, which overspread so much of our northern country during the several parts of the great Glacial Epoch. Dr. Newberry's sketch of Cuyahoga County, the region around Cleveland, also treats of the same fascinating subject; and Prof. Andrews gives quite a chapter of "Conclusions, Theoretical and Practical," on the mode of formation of different varieties of coals.

It only remains to refer briefly to the second volume or second part of Volume I., which treats of the paleontology of Ohio. This work, somewhat larger than the first part, comprises three divisions, as follows: the "Invertebrate Fossils of the Silurian and Devonian Formations," by Prof. F. B. Meek; the "Fossil Fishes of the Devonian Group," by Dr. Newberry; and the "Fossil Plants of the Coal Period" (in part), also by Dr. Newberry. With the exception of these last, the present volume includes only the fossils below the carboniferous rocks.

In these chapters, a great and permanent work has been accomplished for science, in the accurate description and classification of a very large number of interesting fossils, heretofore either undescribed, or described so imperfectly as not to be reliable as a basis for study. The crinoids, mollusks, brachiopods, and trilobites, have been well intrusted to Mr. Meek, whose full and careful discussions are accompanied with an admirable series of plates.

The most remarkable part of this volume, however, is that relating to the fossil fish of the Devonian Age. This period, as is well known, has long been called the "Reign of Fishes," from the great variety of singular and grotesque forms of fish-life which then appeared and peopled the ancient seas. The greatest share in bringing to light this extraordinary series of by-gone types was borne by Hugh Miller, whose discoveries in the "Old Red Sandstone" of Scotland have won for him imperishable fame in the annals of science. The continuation, on this continent, of Miller's discoveries abroad, is here given to the world; and it is no less remarkable, perhaps indeed more so, than were his. The series of fish here described forms an extraordinary addition to our knowledge of the life of the past. The Devonian waters that spread over what is now the greater part of Ohio were inhabited by a strange race of literal sea-monsters, singular in form and gigantic in size, plated and mail-clad, and bearing all manner of elaborate weapons for offense and defense. Among them we may refer to the tribe of Chimæroids, allied to the sharks, now represented only by a few rare species, and which, though well known to have existed in later formations, has never before been discovered in palæozoic rocks. Dr. Newberry has described the new genus *Rhynchodus*, with several species belonging to this group. Still more singular, however, are several genera of ganoid fish, of which only one or two can be referred to here. One of these is *Onychodus*, which carried at the extremity of its lower jaws, where the two rami meet, a vertical set of long, radiating teeth, projecting like the piercing prow of an iron-clad ram. This form is wholly novel. Another is *Deinichthys*, the giant of the period, whose tremendous jaws, shaped like sled-runners, were a couple of feet in length; while the bony buckler that covered the back was from one to two inches in thickness!

But time would fail us to dwell on these interesting accounts; and we can only express our gratification that so much important discovery is now announced and recorded in a permanent form, and congratulate both the gentlemen of the survey and the people and government of Ohio on this great work now so auspiciously approaching its close.

AUTOBIOGRAPHY OF JOHN STUART MILL. New York: Henry Holt & Co. 313 pp., 8vo. Price, $2.25.

THIS is said to be the book of the season, and it is creditable to the season that it is so, for it is a volume of deep and varied interest, as well as of important instruction. Without any dramatic incident or external adventure, the earnest attention of the reader is sustained by a delineation of the quiet career of a man of thought. After all, there is nothing that so concerns us, with regard to a great man, as how his greatness was reached. Mr. Mill has conducted no campaigns, explored no new countries, guided no political administrations, but through his writings he has influenced the thought of his age, in directions where thought issues in action, and his influence may thus have been deeper than if he had wielded the more obtrusive and conspicuous agencies by which men are affected. Obviously, in writing his own life, Mr. Mill did not feel that he had any greatness to take care of, and so he gives a faithful account of his development, taking the reader completely into his confidence, relating his experiences, and offering his opinions and self-criticisms with a candor and unreserve that are quite remarkable. Those who have become interested in Mr. Mill's ideas, and through them in the man, will devour the book with eager curiosity; and those who have not, can hardly fail to be incited by its perusal to the study of his works. We by no means agree with all that Mr. Mill has promulgated, and have given, in another place, the reasons for dissenting from some of his doctrines; but, while holding him as not above criticism, and as having fallen into educational error from the very greatness of his attainments, we do not hesitate to acknowledge our indebtedness to him as a great leader of liberal thought in the present age. His autobiography is valuable as a record of his own mental unfolding; but, beyond this, it has great value as a history of the rise and progress of liberalized opinion in England within the last thirty years, in the promotion of which Mr. Mill had so eminent a

share. A democrat in instinct and feeling, and holding the most radical views on grave questions of social polity and political government, Mr. Mill lived under the most compact and consolidated monarchical, aristocratic, and ecclesiastical system that the world possesses; and the history of his warfare with the ideas in which that system is embedded, while attractive as a philosophical study, has an especial interest for us, who cut loose from that order of things a century ago. Mr. Mill was never an active politician, and only tried his hand at parliamentary work for a short period, late in life; but he was much occupied with political and contemporaneous public questions, and was a virtual leader of a considerable party of men who devoted themselves to active political work.

Mr. Mill's estimates and criticisms of the thinkers of his time, and his analysis of their influence upon himself, are by no means the least interesting portions of his volume. Especially what he says of his mental indebtedness to the influence of his wife will be eagerly perused. He had already given expression to it in terms that have been thought to savor of exaggeration, but all that he had said before is here reiterated with increasing emphasis. In speaking of Carlyle, he observes: "I never presumed to judge him with any definiteness until he was interpreted to me by one greatly the superior of us both—who was more a poet than he, and more a thinker than I—whose own mind and nature included his, and infinitely more." After such a eulogy from the author of the "Logic," the question irresistibly arises, What could have been the preparation of so wonderful a mind? Mr. Mill offers his autobiography confessedly as a study in education, of which he regards himself, as he certainly was, a remarkable exemplification. But why did he forbear to utter a word in relation to the cultivation and history of that extraordinary mind which spanned and included such intellects as his own and Thomas Carlyle's? The question, moreover, will be wonderingly asked, why Mr. Mill, with all his chivalric feeling toward the opposite sex, never once mentions his mother, in the full sketch of his childhood, although his father figures prominently throughout. Perhaps she was not a woman of intellect, and took no part in his early culture; but she had a share in his being, and, whatever may have been the qualities or character of the mother of John Stuart Mill, they should not have been left out of consideration in an account by himself of his own life.

The autobiography is written in Mr. Mill's happiest style, and deserves to be, as it undoubtedly will be, very extensively read.

SEX IN EDUCATION; OR, A FAIR CHANCE FOR THE GIRLS. By EDWARD H. CLARKE, M. D. Boston: James R. Osgood & Co., 181 pp. Price, $1.25.

THIS little volume breaks the monotony of the woman's rights discussion, and exposes one of its current fallacies—the co-education of the sexes.

Whether or not there be sex in mind, Dr. Clarke shows that there is a great deal of it in body, and that this cannot be ignored in the work of education without entailing grave and often fatal evils upon the weaker sex. One would think that there is sufficient physiological knowledge current in the community to prevent an educational system that does not recognize and conform to the radical differences of sex; but, under pressure of a so-called reform, which starts from abstract assumptions rather than physiological data, the strong tendency is to put students of both sexes upon the same footing, regardless of all consequences. Dr. Clarke points out what some of these consequences are. He shows that there is not only a difference in powers of endurance, by which the average feminine constitution is certain to break down when brought into prolonged competition with the average male constitution, but, what is of far more importance, he shows that the feminine constitution is liable under these circumstances to a whole train of derangements and perversions that are peculiar to itself. The fact that women are designed to be mothers, while men are not, is very far from being a mere incidental circumstance that may be left out of the account in their early training. Nor can women, by declining to become mothers, escape from the peculiarities of their nature, so as to assume the career and encounter the discipline of men. The female destiny, which is to give birth to the

race is no such mere incident of humanity. It is a great thing, and its greatness is conditioned upon and attested by the serious sacrifice of other things. Woman is organized throughout her whole nature to the end of maternity, and, if treated in her youth like the opposite sex, which has not this organization, evils are liable to arise that are often numerous, lasting, and fatal. And that which reason says *must* be the result, experience says *is* the result, as Dr. Clarke's book abundantly proves. In his second chapter he makes a very clear statement of the physiological facts and principles involved in the question, and, in his third and main chapter, entitled "Chiefly Clinical," he traces the morbid consequences that have followed a false system of female education. This part of his book is full of startling facts, given in detail, that should arrest the attention of some of our headlong reformers. The book is one that ought to have a wide circulation, and to be issued in a cheaper form.

BRITISH MARINE ALGÆ: being a Popular Account of the Sea-weeds of Great Britain, their Collection and Preservation. Illustrated. By W. H. Grattann. London: "The Bazaar" office, 32 Wellington Street, Strand, W. C.

WHILE the collecting of algæ at the sea-side has long been a graceful and favorite amusement, and many persons have very pretty collections of them, mounted on cards and papers, or arranged in fanciful designs, very few have attempted to learn their names or to study out their structure, fructification, and the principles of their classification. Thanks to the labors of the two Agardhs, Kützing, Thuret, Harvey, Greville, and other eminent phycologists, the scientific knowledge of these plants now rests on a satisfactory and logical basis, and while the study of algæ is difficult in the extreme, there are ample results to reward the patient and careful investigator. The purpose of the little book, the title of which is given above, is to afford to amateurs and to students an easy introduction to the knowledge of algæ, and, if one may judge from the first four parts of the work, all yet received, the author has succeeded admirably in his purpose. The wonder is, that Mr. Grattann has been able to convey so much knowledge about the subject he treats of, and yet be so sparing in the use of technical expressions.

The fact that most of the sea-weeds of the Northern Atlantic coast of the United States occur also about the British Islands, renders this book nearly as available for use here as in Great Britain. The illustrations are very neatly-prepared woodcuts, mostly on a black ground, and are inserted in the body of the work. For advanced students in American phycology the only special treatise is the "*Nereis Boreali-Americana*" of the late Dr. Harvey, of Trinity College, Dublin, a quarto with fifty colored plates, published by the Smithsonian Institution.

MISCELLANY.

Physical Conditions of Inland Seas.—In the August number of the *Contemporary Review* is a paper of great interest by Dr. Carpenter, in which that scientist explains some curious phenomena of inland seas. It is well known that in the open ocean the depths are uniformly colder than near the surface, so that, while the surface-water in some cases approaches 80° Fahr., the temperature is near the freezing-point at depths of one or two miles. This appears to occur where the movement of water is unobstructed by inequalities of the ocean's bed. Where these are present, however, the temperature is more uniform throughout, as in the Sulu Sea, where the water is at 50° at the greatest depths, but in the contiguous but more open China Sea it is at 37° in deep soundings.

From the cause assigned, the inland seas show a uniformity of temperature as compared with the open oceans. While the surface-waters may be of equal temperature, the depths present great contrast. The Straits of Gibraltar are quite shallow, and a free interchange of waters between the Atlantic and the Mediterranean is impossible. From local causes there is frequently no current, or but a very slight one, either one way or the other. As a consequence of this, the cold waters of the deep Atlantic are prevented from flowing in, and a comparatively uniform temperature prevails in the depths of the Mediterranean.

This being the case, there is little or no circulation—the water becomes to some extent stagnant, affecting in a marked manner the development of life in it.

Dr. Carpenter was astonished to find in the Mediterranean very few evidences of life at depths greater than eighteen hundred feet. "The dredge," he says, "brought up barren mud," and, however abundant life may be around its margins, its deeper portions are *azoic*. In the cold but freely-circulating waters of the Atlantic, animals are found at nearly the greatest depths—while the dredge is often filled from soundings of one to two miles. Whence the difference? "I found," says Dr. Carpenter, "the deep waters of the Mediterranean turbid, filled with fine particles of sediment which at last make the ooze of the bottom." The presence of this floating dust, even near the surface, is proved by the blueness of the water. Turbidity is known to be unfavorable to the development of many kinds of marine life. Prof. Dana has shown that a small quantity of sediment thrown upon a portion of a reef kills the polyps on that part, and the growth and distribution of coral-reefs are largely determined by this cause. But, another reason for the absence of life at the bottom of the Mediterranean is, the deficiency of oxygen in its waters in those depths.

Deep waters from the Atlantic and Mediterranean have been boiled off, and in the gases from the first there was twenty per cent. of oxygen, from the latter only five per cent. But of carbonic acid there was from the first only thirty to forty per cent., while the latter furnished sixty per cent. Here, then, in the abundance of carbonic acid, and deficiency of oxygen, is a possible cause for the paucity of life.

But whence arises the deficiency of oxygen. Chiefly, perhaps, from the slow decomposition of organic matters, carried in by rivers and other agencies, and which may add to the turbidity referred to.

This state of things in the Mediterranean, and possibly in other inland seas, evidently arises from absence of circulation of the waters. Winds disturb the surface only, and Dr. Carpenter says there is in the Mediterranean no *thermal* circulation—or circulation which arises from inequality of temperature. It has been said that inequality of density caused by evaporation must produce some vertical circulation of the water, but density from lowering of temperature at the surface never exceeds the density of the deeper waters, and no circulation disturbs or mixes the superimposed masses.

The oxygen from the surface can only reach the deeper waters by diffusion, hence its deficiency at considerable depths. In the Atlantic, and doubtless in all open oceans, the waters are diffused, and mixed by a wonderful system of circulation, the dynamic agencies of which are not present, or only in a modified form, in the inland basins.

The well-known and often-criticised statement of Edward Forbes, that life ceases at a depth of three hundred fathoms, is confirmed by the researches of Dr. Carpenter, in so far as it relates to inland seas, the researches of Prof. Forbes being in the Ægean. The error consisted in applying the same rule to the open oceans, where a different one prevails, and this appears to have been the error of others rather than of Forbes.

Unequal Power of the Eyes.—Probably there are but few persons possessed of equal power of vision in both eyes. This circumstance, as is observed by a writer in *Science Gossip*, will doubtless account for some people being unable to appreciate the binocular microscope. The writer in *Science Gossip* has a friend who always found difficulty in studying with a binocular, in that he could never get the two glasses to blend. In 1851 he attended the Great Exhibition in London, and there his eyes were constantly ranging from short to long distances. After he had left the Crystal Palace he felt that his eyes were very much fatigued, and was at a loss to understand the meaning of it. By this and other circumstances he discovered that there was a *focal difference* in his eyes. One eye was *far*-sighted, while the other was *near*-sighted. For reading-purposes he wears a pair of spectacles in which the one glass is made for the *far* sight, while the other is a plain glass, the left eye being *near*-sighted, and consequently requiring no aid from specta-

cles with which to read. Instances are cited of persons who, while employing both eyes for ordinary vision, usually employ only one in reading. If any difference of the kind exists between the visual powers of a pair of eyes, it may be readily detected. Hold up a piece of card before one eye, so as to cut off its field of view, and then look at some object before you with the other. Then gradually bring the card before the other eye, and view the same object. If the object is seen with the same distinctness in each case, then your eyes are perfect as regards the balance of their *foci:* if not, then there is focal difference more or less decided. It would no doubt be advisable to take account of this very frequent difference of focus, in selecting a pair of spectacles.

Natural Grafting.—A writer in the *Gardener's Monthly* for August gives some instances of anastomosis, or natural grafting of plants, which came under his own observation. In THE POPULAR SCIENCE MONTHLY for March, 1873, we gave Goeppert's theory, accounting for the continued life and growth, in some cases, of the stumps of pine and fir trees. Goeppert's explanation of the phenomenon is, that the roots of these stumps are nourished with sap derived from the roots of trees in their neighborhood, with which they are in contact. Such roots are found deeply embedded in one another, and so consolidated as to become practically continuous. The writer in the *Gardener's Monthly*, after briefly stating these facts, describes similar phenomena which he observed last spring among the branches of two apple-trees.

In one of these the limbs so crowded one another that it was resolved to cut one away. It was accordingly sawed off; but still it did not fall. It was then found that the dismembered branch was firmly united to a limb situated beneath it. With a hatchet the writer then cut it near the point of union; but the end of the branch still lives and thrives, bearing blossoms and fruit in season. Another tree was found, but a few yards distant from the first, which exhibited the same phenomenon of natural grafting. "I had never before," continues the writer, "seen or heard of such a case in an apple-tree, but I do not think it so difficult to account for as the condition of the coniferous trees. It is natural to suppose that the motion of the wind may occasion abrasion of the bark on the limbs of apple-trees, and thus prepare them for this natural grafting; but, in the case of roots underground, such cause for union cannot operate. In both these instances, it is worthy of remark that the trees were of the kind called American Pippin, or Grindstone." But surely there is no difficulty in conceiving of two roots from different trees growing into contact, when compressed together into a narrow space owing to the refractory nature of the soil. Under such circumstances they might rub away each other's bark at the point of contact, and establish between themselves such an exchange of living force as would constitute a life in common.

The Quinine-Supply.—The cultivation of the cinchona-tree in India, which was commenced in 1860, is making satisfactory progress. Near Darjeeling are two large plantations, one owned by the government, and the other by an association. The three principal varieties of the cinchona, *officinalis*, *calisaya*, and *succirubra*, were all planted at Darjeeling, with a view to find which variety would thrive best there. The officinalis, or gray-bark variety, failed utterly; the calisaya, or yellow-bark, has fairly succeeded; but the succirubra, or red-bark, has prospered beyond all expectation. There are now 2,500 acres under succirubra. A moderate estimate gives the produce of these plantations for the next three years at 200,000 lbs., calculated to produce 6,000 lbs. of quinine, and an equal amount of other valuable alkaloids.

Some years since a quinine famine appeared to be inevitable, as the cinchona-trees were fast disappearing in South America. "The drug," writes Berthold Seemann, "is almost as indispensable to mankind as air itself, and, aided by this silent agent, Europeans have been able to establish happy homes, busy factories, and flourishing colonies, in districts which, without this invaluable aid, would have simply become their graveyards. Our only wonder is, how we could ever have done without it, and what would become of us if the supply

should ever fail. And the supply does begin to fail (1863), fail rapidly. It is known that 1,200,000 lbs. of Peruvian (or cinchona) bark are annually imported into England; and it is estimated that no less than 3,000,000 lbs., and probably a much greater quantity, are consumed every year throughout the world. The demand is daily increasing, and the drain upon the forests of New Granada, Ecuador, Peru, and Bolivia, has now been going on for two centuries.

"Thus, what with the excessive and unceasing demand for bark, and the reckless manner of collecting it, large tracts of country, formerly famous for their abundant yield, are now entirely denuded of almost every trace of cinchona-vegetation."

The Caterpillar Nuisance in Philadelphia.—For several years the measuring-worm preyed on the leaves of the trees in Philadelphia to such an extent that, early in the summer, scarcely any foliage would be left remaining. The English sparrow was introduced to counteract the destroyer, and performed its work so effectually that after a year or two no more measuring-worms were to be seen. But now, according to the *Medical Times*, another enemy of the trees has made its appearance, the caterpillar of the *Orgygia leucostigma* moth. As long as the measuring-worm was left unmolested, the caterpillar, which comes late in the season, found the struggle for existence a sharp one, its natural provision having been previously consumed by the worm. Now, however, it finds abundance of food, and is consequently prospering and rapidly multiplying. The sparrows will not attack it, protected as it is by its hairy coat. Perhaps some other feathered exterminator can be found to destroy the tribe; but, inasmuch as the sparrow is a very stubborn and pugnacious little fellow, it is a question whether he will allow any other bird to trespass on his domain. Meanwhile, the caterpillar pest is assuming formidable proportions, as witness the following passage from our medical contemporary: "At present, very many trees in this city have again put on the familiar, woe-begone look of old, hiding their misery with the merest tatters and shreds of leaves. 'But the new-comer doesn't drop on you!' Doesn't he though? If he does not drop he crawls, or gets on some way or other; and the man who has felt his long hairs tickling his neck, struck for a fly, and found in his hand a bare and *bursted* carcass, on his shirt-collar a stain, and down his back a bunch of tickling hairs, will vote the 'survival of the fittest,' in its latest form, an unmitigated nuisance."

Eating Alcohol.—It has been generally supposed that the alcohol formed in the primary fermentation of bread was all expelled by the process of baking. Mr. Thomas Bolas, of London, has communicated to the *Chemical News* the result of some experiments on this point. He shows that when about two ounces of ordinary bread is mixed with water and distilled, and the distillate is afterward purified, a perceptible quantity of alcohol may be obtained. He made quantitative analyses of six samples of fresh bread, obtained in so many shops in London, which gave of alcohol an average of 0.314 per cent. So that, when a man has eaten 100 pounds of fresh bread, he has consumed with it a little more than five ounces of pure alcohol.

The Grape-vine Blight.—M. Planchon, of the French Academy, an eminent botanist and entomologist, visited this country last summer to study the habits of the *phylloxera*, an insect which is ravaging the vineyards of France. Prof. Planchon was the first to discover that the blight of the grape-vine is the work of the *Phylloxera vastatrix;* and then Prof. Riley, State entomologist of Missouri, proved the American origin of the redoubtable ravager.

M. Planchon's investigations in this country fully corroborate Prof. Riley's observations as to the identity of the European and American insect, and as to the comparative immunity of certain American grape-vines. The Missouri entomologist's discovery of a species of *acarus*, which is the deadly enemy of the *phylloxera*, has attracted much attention abroad, and M. Planchon takes a supply of *acari* back with him to France, hoping by their aid to check the career of the destroying insect.

For five years, every remedy that imagination could suggest, under the stimulus of a reward of 20,000 francs, has been tried

in France, but hitherto without success. The latest remedy, one from which great results were expected, is sulphuret of carbon. It was held that this substance is fatal to the *phylloxera*, but perfectly harmless to the vines. As to the first point, there appears to be no reason to question the beneficial effects of the sulphuret, but not so with regard to the second, if we may put any faith in the experiments of Lecoq de Boisbaudrant. According to him, sulphuret of carbon kills the vine as well as its parasite.

Migrations of Insects.—The following historical facts will give an idea of the enormous magnitude sometimes attained by migrating swarms of insects. After the defeat of Poltava, while retreating through Bessarabia, Charles XII.'s army was marching through a defile, when suddenly the men and horses were brought to a halt, being blinded by a living hail precipitated from a thick cloud which intercepted the light of the sun. The coming of the locusts was heralded by a whizzing sound like that which precedes a storm of wind, and the noise of their wings and of their bodies as they clashed together was greater than the roar of breakers on the sea-shore! General Levaillant saw, at Philippeville, Algeria, a cloud of locusts twenty to twenty-five miles in length, which, when it descended to the earth, formed a layer over an inch in thickness.

Toward the close of 1864 the cotton plantations of Senegal were destroyed, and a living cloud was seen to pass over the country from morning till night: the rate at which it moved showed that it was about fifty miles long; and this was only the vanguard, for when the sun went down a still denser cloud was moving on. The English traveller, Barrow, states that in Southern Africa, in the year 1797, these insects covered the ground to the extent of two square miles, and that having been driven by the wind toward the sea, they formed a drift near the coast nearly four feet in depth and fifty miles long! After the wind changed, the stench of their putrefying carcasses was recognized at the distance of a hundred and fifty miles.

The famines produced by the voracity of these acridians are not the only evils they cause to men and animals; a pestilential epidemic is oftentimes the result of the foul emanations from their rotting bodies. The invasions of these insects are veritable national calamities. In 1835 China was ravaged by them, and the sun and moon were obscured. Wherever they alighted the finest and richest crops were instantly devoured and the fields left bare; even the contents of the barns were to a great extent consumed by them. The people fled in alarm to the mountains. In the submerged districts, where there were no crops to devour, the locusts penetrated into the houses and destroyed the people's clothing. These ravages, which began in April, continued without interruption till the season of frost and snow.

Animal-like Functions of Plants.—In the Biological Section of the late meeting of the British Association, Dr. Burdon Sanderson read a paper on the electrical phenomena which accompany the contractions of the leaf of Venus's-Flytrap. It was remarked that in those structures in the higher animals which are endowed with the property of contracting when stimulated, viz., nerve and muscle, this property is associated with the existence of voltaic currents which have definite directions in the tissue. It became suspected that such was similarly true of the Sundew (*Drosera*), and Venus's-Flytrap (*Dionæa muscipula*) and some other plants. Mr. Darwin furnished the plants necessary for experiment to Dr. Sanderson in the laboratory of University College, London. The result is, that the anticipations of the existence of voltaic currents in these parts have been confirmed, particularly in the leaf of *Dionæa*. The doctor has established the fact that these currents are subject, in all respects in which they have been investigated, to the same laws as those of muscle and nerve. This may be regarded as one of the most interesting of recent biological discoveries.

Natural Varieties.—Nature's best efforts in the vegetable kingdom sometimes seem to be reached *per saltum*, and without any aid from man. Recently in England a first-class certificate was given by the Royal Horticultural Society for a fine variety of gooseberry,

under the name "Kerson's Seedling Gooseberry." It turns out to be no garden seedling, but a wild one originally taken from a common hedge in the neighborhood of Peterborough. In like manner, the celebrated Bess Pool apple was originally discovered in a wood near Nottingham. It is noteworthy that the famous Lawton blackberry of this country was found wild at New Rochelle, in Westchester County, New York. It may be remarked of all these, and similar seedlings, that their specific excellence cannot be propagated by seeds but only by cuttings, stolons, or grafts.

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Malformations.—Last winter one of our pupils at New Brunswick, N. J., communicated the fact that he had purchased, the previous autumn, of a huckster-woman in Newark, a pair of young ducks, each having four wings. The woman had twelve for sale, and said that the eggs were laid by a well-formed bird; that she hatched a brood of sixteen, every one of them having four wings. The youth said that his birds used both pairs of wings in flying, that is, in moving rapidly on the surface of the pond. They did not live long. Whether this was due to any defective vitality in the birds, or to any extraneous cause, could not be learned. But we turn from these traditionary facts to a catastrophe, which our own eyes have inspected, as having befallen a family of cats.

About a mile and a half from Freehold, N. J., live an intelligent family who have had for several years an annual litter of malformed cats. Several years ago a young male cat was brought from Allentown, some twenty miles distant. This cat had a deformity in one front-foot, which had six toes. It coupled with a cat of normal form and parts, and a litter of four or five was the result, all with six-toed front-feet. The she-cat became troublesome, getting into the pantry, and so was sent off. The kittens were disposed of, except one. With this the paternal cat united, and the result was four kittens, each having six toes on each fore-foot, and five on each hind-foot. This intermixing, as I understand, by this Grimalkin Turk, has gone on for some four years, and to-day, July 29th, I examined one of his daughters, some three months old, which has *six toes* on each of the hind-feet, and *seven toes* on each of the fore-feet. The fore-feet are bifurcated; that is, they have, as it were, each two paws to one foot, the outer paw of each foot being much the larger, and having four toes; and the inner, or smaller paw, on each foot, having three toes. This kitten was one of a litter of four, all malformed precisely alike. On some points I could not get the exact information desired. But I should think that the vitality of these cats is becoming less and less, as they do not become common. To me it seems astounding when I attempt to conceive of the physical equation which enters into this erratic conception — the minuteness of the abnormal material which, plus the normal substance as imparted by the spermatozoön, gives the initial impulse to a result so eccentric. If, as Goethe declared, "it is in her monstrosities that Nature reveals to us her secrets," one would like to know something of the mode and motive of such a distribution of the life-force. During our inspection of Miss Tabbie it was all very well so long as we stroked her back with one hand. She purred, as expressive of true feline luxuriousness; and, what is not common, she even licked the other hand as indicating affection. But, when we meddled with her extremities, she evidently regarded it as taking personal liberties with unpleasant peculiarities; and instantly rewarded our duplicity by investing in our hand the seven talons concealed in that duplex napkin.—Samuel Lockwood, *in American Naturalist.*

NOTES.

Prof. Eaton, of Yale College, kindly calls attention to an inaccuracy in the sketch of Dr. J. D. Hooker published in The Popular Science Monthly for December, 1873. It is there stated that Dr. Hooker was an only son. Prof. Eaton writes: "In 'Filices Exoticæ,' p. 36, Sir W. J. Hooker refers to the kindness formerly shown by Dr. McFadyen, of Kingston, Jamaica, 'to a beloved son who fell a sacrifice to yellow fever while under his hospitable roof.' The widow of this son, Mrs. William Hooker, is still living at Glasgow, and I saw her several times at Dr. Hooker's house in Kew, in 1866." Prof. Eaton adds the interesting fact that the grandfather of Dr. Hooker on his mother's side, Dawson Turner, Esq.,

was an excellent botanist, and the author of "Spicilegium Musculogiæ Hibernicæ," a treatise on Irish mosses, published at Yarmouth in 1804. The earliest botanical writings of the elder Hooker were, to a great extent, also upon mosses.

In the year ending April 1, 1873, there were bred in the Central Park Menagerie, 2 lions, 2 pumas, 1 leopard, 1 spotted hyena (the first born in America), 1 camel, and 1 Cape buffalo. The total number of animals in the menagerie is now: quadrupeds, 199; birds, 347; reptiles, 35. The additions during the year numbered 48, viz., 25 mammals, 21 birds, and 2 reptiles.

The Minnesota State Geologist is authority for the statement that there is enough iron-ore in the neighborhood of the Black River Falls, in that State, to supply the whole demand of the Union for the next ten centuries.

The following extract from a letter recently received in London, and sent by Dr. Beke to the *Times*, gives the latest information regarding the whereabouts and condition of Dr. Livingstone:

"Borna, *August* 12, 1873.

"I am proceeding, to-day or to-morrow, to Munuco, Upper Congo. In a few days we expect there the Livingstone Expedition, which cannot proceed from St. Salvador. Livingstone himself is a prisoner in a town, twenty days from here, but is entirely without means to pay his ransom. Assistance has, however, been sent to him, and he may be here in a month or so."

In the department of the Vienna Exposition devoted to medical and surgical instruments and preparations, certain anatomical specimens exhibited by Dr. Marini, of Naples, have attracted special attention. He has invented processes for the preservation of bodies, both in the leathery or tanned state, and in the natural condition of the tissues. In the latter case, the tissues preserve their natural softness and even their transparency. Among the specimens exhibited, was a foot which had been prepared in 1864. On making an incision into this, the underlying tissues appeared to be as fresh as in a cadaver one day old. The tendons, ligaments, and fatty tissue, preserved all their usual characters, the muscles alone being in a slightly inferior state of preservation. The same solutions which are used for embalming bodies may be employed in the treatment of malignant ulcers. For this purpose they are largely diluted. Dr. Marini has made experiments in the Naples Hospital, with a view to determine the value of his solutions in such cases, and the report of the surgeons as to the efficacy of the treatment is very favorable.

Dr. F. Grace-Calvert, the eminent chemist, died, Friday, October 24th, aged fifty-nine. He received his early education in France, and received the appointment as assistant chemist at the Gobelin tapestry-works, under his master, Chevreul. In 1846 he was appointed Professor of Chemistry to the Manchester Royal Institution, a post which he held down to his death. As an analytical chemist his renown was world-wide.

During the past summer, two ship-loads of oysters were imported into England from Virginia for transplantation. If this venture proves a success, eight or ten steamers will be sent from England to Hampton Roads for oysters next season.

According to statistics collected by Dr. T. Harrington Tuke, the number of lunatics in England increased during the ten years ending June, 1873, from 1.86 per thousand of the population to 2.58. Dr. Tuke is inclined to attribute this increase to the advance in wages, which allows the laboring class enlarged means of undue indulgence

The trials at Williamshaven with the new Hertz torpedo gave the most surprising results, the torpedoes disposing of the objects attached with the utmost punctuality and in a strikingly summary manner. Their construction is as yet a secret; but there is no doubt that the German navy is now in possession of a most powerful and destructive weapon which will not only effectually protect the coasts of the empire, but will also enable the government to employ all its resources in building ships for aggressive purposes.

The Peruvian Amazons Exploring Commission lately issued a report, from which it appears that malarious fever prevails on both banks of the mighty river, causing a large mortality among the native population. Adults and children are given to the filthy habit of geophagy or clay-eating, a practice productive of innumerable physical evils. It is common to find on the Amazons children of three years of age smoking, and not averse to rum.

Prof. Palmieri, director of the Observatory of Mount Vesuvius, has constructed for the Empress of Russia a metallic thermometer, which gives a signal at every appreciable change of temperature. The apparatus is so sensitive that the indicator is almost always moving. When the variations of temperature reach a certain degree, little bells begin to ring, and notice is thus given of the rising or falling of the mercury. The instrument also marks the highest and lowest degrees of temperature which have taken place during a certain period.